SRM Institute of Science and Technology
College of Engineering and Technology

Batch-1
SET-A

DEPARTMENT OF ECE

SRM Nagar, Kattankulathur – 603203, Chengalpattu District, Tamil Nadu

Academic Year: 2022-23 (Even)

Test: CLAT-2 **Date: 04-04-2023**
Course Code & Title: 18ECC302J–Microwave and Optical Communication **Duration: 8.00 AM–9.40 AM**
Year & Sem: III / VI **Max. Marks: 50**

	18ECC302J - Microwave & Optical Communications	**Program Outcomes (POs)**														
		Graduate Attributes												**PSO**		
S. No.	**Course Outcomes (COs)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
1	Demonstrate the knowledge on the theory of microwave transmission, microwave generators and associated components	3	-	-	3	-	-	-	-	-	-	-	-	-	-	1
2	Analyse the microwave passive devices and components	-	2	-	3	-	-	-	-	-	-	-	-	2	-	-
3	Incorporate microwave measurements and associated techniques with equipment	-	-	3	2	-	-	-	-	-	-	-	-	-	-	3
4	Gain knowledge of the fundamentals on light transmission through fiber	-	3	-	2	-	-	-	-	-	-	-	-	-	-	1
5	Develop a basic optical communication system	-	3	-	-	3	-	-	-	-	-	-	-	2	-	-
6	Implement the working principle of microwave components, microwave measurements, optical sources, detector and fibers	-	-	3	-	3	-	-	-	-	-	-	-	-	-	3

Part – A
(5 × 10 = 50 Marks)
Instructions: Answer any FIVE Questions.

Q. No.	**Question**	**Marks**	**BL**	**CO**	**PO**
1	**(A)** In the Tee junction, if the arm parallel to the H field is fed with power P, then what will be the power at the remaining ports? (a) P/4 at each port (b) P/3 at each port **(c) P/2 at each port** (d) 2P at each port	1	1	2	2
	(B) Why conventional parameters (H, Y, Z) cannot be used for microwave frequency measurement. **Ans. Three points 3 marks** If the frequencies are in the microwave range, however, the H, Y, and Z parameters cannot be measured for the following reasons: 1. Equipment is not readily available to measure total voltage and total current at the ports of the network. 2. Short and open circuits are difficult to achieve over a broad band of frequencies. 3. Active devices, such as power transistors and tunnel diodes, frequently will not have stability for a short or open circuit.	 1 1 1	1	2	2
	(C) The incident power is 100 W for a directional coupler. It has a coupling factor of 25 dB and directivity of 40 dB. Find the coupled		3	2	4

	and isolated port power. **Ans.** Given P1 =100 W, C= 25 dB and D=40 dB Coupling factor (C) = 10 log $\frac{P_1}{P_4}$ = 10 log $\frac{100}{P_4}$ = 25 So, $\frac{100}{P_4}$ = 316.23 **Coupled power P_4 = 0.316 W-----**(i) Directivity (D) = 10 log $\frac{P_4}{P_3}$ = 10 log $\frac{0.316}{P_3}$ = 40 So, $\frac{0.316}{P_3}$ = 1000 **Isolated power (P_3) = 31.6 µW -----** (ii)	3 3			
2	**(A)** In hollow rectangular waveguide______ **(a) The phase velocity is greater than the group velocity.** (b) The phase velocity is less than group velocity. (c) The phase velocity is equal to the velocity of light in free space. (d) The phase velocity is equal to the group velocity. **(B)** The guided wavelength for a frequency of 20,000 MHz is 6 cm when the dominant mode is propagated in an air-filled rectangular waveguide. Find (i) The cut-off wavelength of the waveguide. (ii) The height of the waveguide. (iii) The width of the waveguide. **Ans.** Given Dominant mode TE_{10} so, m=1, n=0 f= 20,000MHz = 20 GHz, λg = 6 cm For TE_{10} mode λc =2a { $\because \lambda c = \frac{2ab}{\sqrt{m^2b^2+n^2a^2}}$ } $\lambda_0 = c/f = \frac{3x10^{10}}{20x10^9} = 1.5$ cm $\lambda g = \frac{\lambda_0}{\sqrt{1-\left(\frac{\lambda_0}{\lambda c}\right)^2}}$ substituting the values of λg and λ_0 in the above equation $6 = \frac{1.5}{\sqrt{1-\left(\frac{1.5}{\lambda c}\right)^2}}$ λc = 1.549 cm-----------(i) λc > λ0 the wave propagates and λc=2a for the TE_{10} mode, so a= $\frac{\lambda_c}{2} = \frac{1.549}{2}$ =0.7745 cm-------(ii) b= $\frac{\lambda_c}{4} = \frac{1.549}{4}$ = 0.387 cm { ∵ a= 2b}--------------(iii)	1 3 3 3	2 3	2 2	2 4

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<td>(A) If port 3 and port 4 of a four-port circulator are terminated by the matched load, then the resultant device will have the characteristics of
(a) Phase shifter
(b) Attenuator
(c) Isolator
(d) Power divider</td>
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<td>(B) Design a non-reciprocal four-port transmission device using hybrid Tees and non-reciprocal $\frac{3\pi}{3}$ phase shifters and explain its working with S-matrix.
Ans. Explanation: 5 marks, Diagram: 2, S-matrix: 2

A Circulators
A circulator is a multiport junction in which the wave can travel from one port to the next immediate port in one direction only as shown in Fig. 6.32(a). Commonly used circulators are three-port or four-port passive devices although more number of ports is possible.

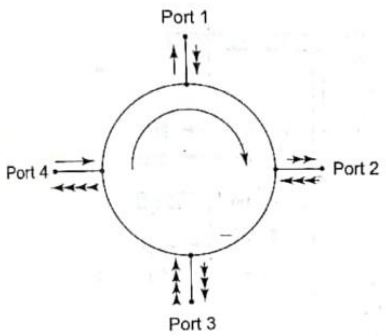

Fig. 6.32(a) Schematic diagram of a four-port circulator

(a) Four-port circulator A four-port circulator can be constructed from two magic-T's and a non-reciprocal 180° phase shifter or a combination of two 3 dB side hole directional couplers with two non-reciprocal phase shifters

In Fig. , an input signal at Port 1 is split into two in-phase and equal amplitude waves in the collinear arms b and d of the magic-tee, T_1 and added up to emerge from Port 2 in the magic tee, T_2. On the other hand a signal at Port 2 will be splitted into two equal amplitude and equiphase waves in the collinear arms of the magic-tee, T_2 and appears at point b and d out of phase due to presence of the non-reciprocal 180° phase shifter. These out-of-phase waves add up and appear from Port 3 in the magic-tee, T_1. In a similar manner, an input signal at Port 3 will emerge from 4, an input at Port 4 will appear at Port 1. Thus the circulator property is exhibited.

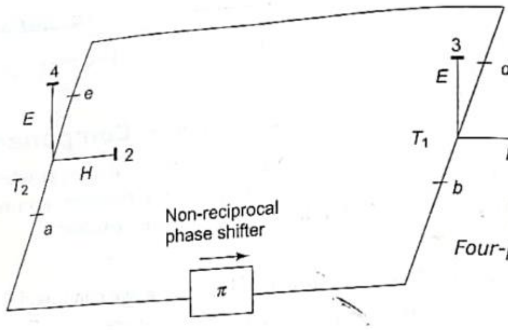

Fig.
Four-port circulators

$$[S] = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$</td>
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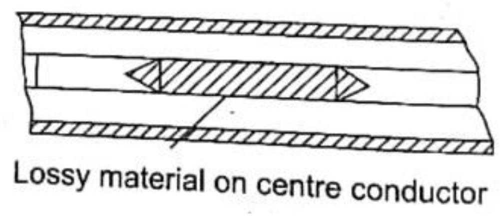
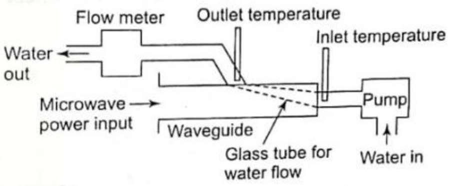
4	**(A)** What will be the outpower of a 3-dB power divider, when the input power is 1 dBm? (a) - 0.5 dBm at each port (b) 0.5 dB at each port (c) - 1 dBm at each port **(d) -2 dBm at each port**	1	3	2	2
	(B) If the input power of a microwave system is 100 dB. To reduce this power by 20 dB which device can be used? Name that device and briefly explain it.		3	2	2
	Ans. Explanation 2 marks and Diagram 2 marks Attenuators are passive devices used to control power levels in a microwave system by partially absorbing the transmitted power. To reduce input power by 20 dB, a fixed attenuator with 20 dB loss will be used. A coaxial fixed attenuator uses a film with losses on the center conductor to absorb some of the power The fixed waveguide type consists of a thin dielectric strip coated with resistive film and placed at the center of the waveguide parallel to the maximum E field. Induced current on the resistive film due to the incident wave results in power dissipation, leading to attenuation of microwave energy. The dielectric strip is tapered at both ends up to a length of more than half wavelength to reduce reflections.	2			
	 **Fig.** Coaxial line fixed attenuator	2			
	(C) Calculate the VSWR of a rectangular waveguide of 4 X 2.5 cm operating at 10 GHz. Assume that wave travelling in dominant mode inside the waveguide and the distance between twice minimum power point is 1mm. **Ans.** $\lambda_0 = c/f = \frac{3\text{x}10^{10}}{10\text{x}10^{9}} = 3$ cm $\lambda c = 2a = 2 \text{ x } 4 = 8$ cm $\lambda g = \frac{\lambda_0}{\sqrt{1-\left(\frac{\lambda_0}{\lambda c}\right)^2}} = 3.236$ cm For double minimum method VSWR is given by: $\text{VSWR} = \frac{\lambda g}{\pi(d2-d1)} = \frac{3.236}{\pi(0.1)} = 10.3$	5	3	3	3

5	**(A)** If the source impedance is perfectly matched with the load, then the value of the reflection coefficient and VSWR are respectively (a) 1,0 **(b) 0,1** (c) 0,0 (d) 1,1	1	1	3	3
	(B) A microwave source is giving power in the 50 W range. Find out the sensor that can be used to measure this power and explain its measuring methods with a suitable diagram. **Ans. Method 1: 4 marks, Method 2: 5 marks** High power microwave measurements can be conveniently done by the calorimetric method which involves conversion of the microwave energy into heat, absorbing this heat in a fluid (usually water) and then measuring the temperature rise of the fluid as shown in Fig. 1 . There are two types: one is the direct heating method and another is the indirect heating method. In the direct heating method, the rate of production of heat can be measured by observing the rise in the temperature of the dissipating medium. In indirect heating method, heat is transferred to another medium before measurement. In both the methods static calorimeter and circulating calorimeter are used. ***Static Calorimeters*** It consists of a 50 ohm coaxial cable which is filled by a dielectric load with a high hysterosis loss. The load has sufficient thermal isolation from its surrounding. The microwave power is dissipated in the load. The average power input is given by $$P = \frac{4.187\ mC_pT}{t} \text{ watts}$$ where, m = mass of the thermometric medium in gms C_p = its specific heat in cal/gms T = temperature rise in °C t = time in sec. ***Circulating Calorimeters*** Here the calorimeter fluid (water) is constantly flowing through a water load. The heat introduced into the the fluid makes exit temperature higher than the input temperature. Here average power $$P = 4.187\ v\ d\ C_p\ T \text{ Watts}$$  **Fig. 1** *Microwave calorimeter* where, v = rate of flow of calorimeter fluid in cc/sec d = specific gravity of the fluid in gm/cc. T = temperature rise in °C C_p = specific heat in cal/gm A disadvantage of calorimeter measurements is the thermal inertia caused by the lag between the application of microwave power and the parameter readings.	4 5	2	3	4
6	**(A)** The input power of a microwave transmission line is 50 dB. But due to impedance mismatch 4 dB power is reflected from the input port and the attenuation of the transmission line is 2 dB/m then what will be the output power of the transmission line of length 10 m? (a) 30 dB (b) 46 dB **(c) 26 dB** (d) 44 dB	1	3	3	4

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Ans. Method name: 1 mark, Explanation: 4 marks, Diagram: 4 Marks
Method: Down Conversion method

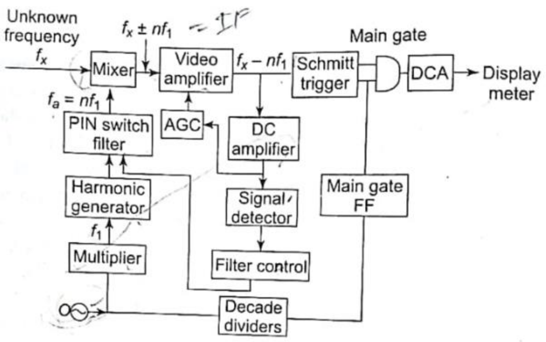
13.12.3 Down Conversion Method
An accurate measurement of microwave frequency can be done by means of a heterodyne converter. A heterodyne converter (Fig. 13.25) down converts the ~~unknown frequency~~ f_x by mixing with an accurately known frequency f_a, such that the difference $f_x - f_a = f_{IF}$ is amplified and measured by the counter. The frequency f_a is selected by first multiplying a local oscillator frequency (known) to a convenient frequency f_1 and then passing it through a harmonic generator that produces a series of harmonics of f_1. The appropriate harmonic $nf_1 = f_a$ is selected by the tuning cavity such that f_a can be added with f_{IF} and display f_x (counter reading $+ f_a$), the unknown frequency. In practice, the system starts with $n = 1$ and the filter frequency is selected by a feed back mechanism from IF stage until an IF frequency in the proper range is present. Typically, f_1 = 100 to 500 MHz for a range of f_x up to 20 GHz. For better accuracy a low noise oscillator and noiseless multiplier are to be selected.


Fig. 13.25 Down conversion method</td><td>

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<tr><td>7</td><td>(A) The Deschamp’s method is used for
(a) ABCD Parameter measurement
(b) Scattering parameter measurement
(c) Quality factor measurement
(d) Frequency measurement

(B) Which parameter is used for frequency selectivity measurement of a cavity resonator and how will you measure that parameter through VSWR measurement, explain it.
Ans. Parameter name: 1 mark, Explanation: 6 marks, Diagram: 2 Marks
Parameter: Quality Factor (Q)</td><td>1

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13.13.1 Slotted Line Measurement of Q

A slotted line may be used to measure the Q of a reflection type cavity which is normally used in a microwave tube, through pure VSWR measurements or through measurement of the shift in position of a standing wave minimum as the generator frequency is varied. Here the VSWR in the line that feeds the cavity is uniquely related to the variation in amplitude of the cavity input reflection coefficient and the shift of minimum is related to the variation of phase angle of the complex voltage reflection coefficient. The measurement set-up is shown in Fig. 13.26. The half-power frequency is found directly from the VSWR measurement, where the equivalent resonator reactance is assumed to be equal in magnitude to the equivalent resonator resistance. If $Z_{in} = R + jX$ is the input impedance in the vicinity of resonance of the cavity, VSWR

$$S = \frac{|Z_{in} + Z_0| + |Z_{in} - Z_0|}{|Z_{in} + Z_0| - |Z_{in} - Z_0|} \tag{13.74}$$

At resonance frequency f_0, $X = 0$, so that minimum VSWR S_0 is

$$\begin{aligned} S_0 &= R/Z_0, \quad \text{if} \quad R > Z_0 \\ &= Z_0/R, \quad \text{if} \quad R < Z_0 \end{aligned} \tag{13.75}$$

At half-power frequencies f_1 and f_2 of the unloaded cavity, $X = R$, so that

$$S_1 = \frac{\sqrt{[(R+Z_0)^2 + R^2]} + \sqrt{[(R-Z_0)^2 + R^2]}}{\sqrt{[(R+Z_0)^2 + R^2]} - \sqrt{[(R-Z_0)^2 + R^2]}} \tag{13.76}$$

or,

$$S_1 = S_0 + \frac{1}{2S_0} + \sqrt{\left(S_0^2 + \frac{1}{4S_0^2}\right)}; \; R > Z_0$$

$$= 1/S_0 + S_0/2 + \sqrt{(1/S_0^2 + S_0^2/4)}; \; R < Z_0 \tag{13.77}$$

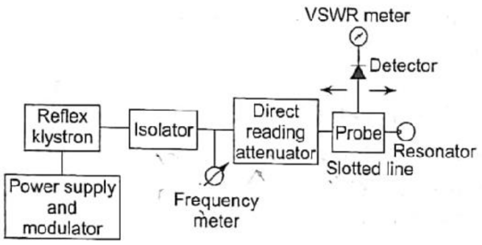

Fig. 13.26 *Slotted line measurement of Q*

The unloaded $Q_0 = f_0/(f_1 \sim f_2)$ can be determined from the above measurements. For a loaded cavity, minimum value S_0 as well as $\Delta f = f_1 \sim f_2$ increase and this results in a lower value of Q. The accuracy of measurement lies on the half-power VSWR and half-power bandwidth. In this method the measurement errors include the departure from square-law behaviours of the probe detector, frequency instability of the source, generator mismatch, probe and generator interaction at high VSWR.

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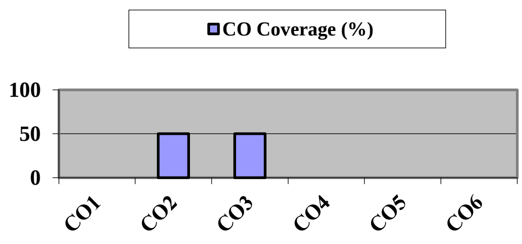
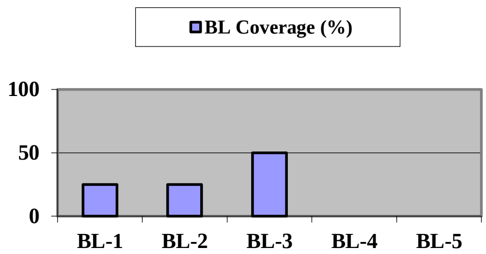
Course Outcome (CO) and Bloom's level (BL) Coverage in Questions





Evaluation Sheet

Name of the Student:

Register No.:

Part - A (5 × 10 = 70 Marks)					
Q. No.	CO	PO	Max. Marks	Marks Obtained	Total
1 (A)					
1 (B)					
1 (C)					
2 (A)					
2 (B)					
3 (A)					
3 (B)					
4 (A)					
4 (B)					
4 (C)					
5 (A)					
5 (B)					
6 (A)					
6 (B)					
7 (A)					
7 (B)					

Consolidated Marks:

CO	Max. Marks	Marks Obtained
2	35	
3	35	
Total	70	

PO	Max. Marks	Marks Obtained
2	11	
3	25	
4	34	
Total	70	

Signature of the Course Teacher

M. Kumaravel 30/3/23

Signature of Question Paper Setter

30/3

Signature of the Course Coordinator

S. SUHASINI

30/3/23

Signature of the Academic Advisor