USN

VTU BE Degree Examination – Feb/Mar 2022

CBCS SCHEME

17EC71

USN 1CR17EC010

Seventh Semester B.E. Degree Examination, Feb./Mar. 2022
Microwaves and Antennas

Time: 3 hrs. Max. Marks: 100

Note: ***Answer any FIVE full questions, choosing ONE full question from each module.***

Module-1

1 a. With neat diagrams, explain the concept of reflex system. **(10 Marks)**

b. Calculate the transet time at the cavity gap, transit angle and velocity of electron leaving the gap for 2- cavity klystron that operates at 4GHz with a DC beam voltage of 5kV and 2mm cavity gap. **(06 Marks)**

c. Define VSWR. **(04 Marks)**

OR

2 a. Obtain the transmission line equations from fundamentals. **(10 Marks)**

b. A transmission line has a resistance of 2Ω/m with an inductance value of 8n H/m. The conductance of the line is 0.5m mho/m and capacitance is 0.23p.F. f = 1GHz. Find the characteristics impendence of the line and the propagation constant. **(04 Marks)**

c. What is a Smith chart? Explain the different measurement that can be determined using a smith chart? **(06 Marks)**

Module-2

3 a. Explain the properties of S parameters as applicable to a microwave network. **(10 Marks)**

b. Write short notes on :
   i) Coaxial connectors and adapters
   ii) Attenuators. **(10 Marks)**

OR

4 a. What is a Magic Tee? Explain its properties. Also determine its S-matrix. **(10 Marks)**

b. Explain a directional coupler and write its S-matrix. **(10 Marks)**

Module-3

5 a. A certain microstripline has the following parameters.
$\varepsilon_r = 5.23$ h = 7 mils t = 2.8 mils w = 10mils [Note : 1mil = 0.0254mm]. Calculate the characteristic impedance of line (Z_0). **(04 Marks)**

b. Explain a parallel strip line, with neat diagram and relevant equations. **(06 Marks)**

c. Define the following :
   i) Radiation Intensity
   ii) Aperture of Antenna
   iii) Beam area
   iv) Directivity
   v) Reduction pattern. **(10 Marks)**

OR

6 a. Derive Friis transmission formula. **(08 Marks)**

b. Compute the power received by an antenna in case of transmission over a distance of 150km at 500MHz. When gain G of antennas used are both 25dB. (P_T = 200W). **(06 Marks)**

c. Obtain a relationship between directivity and effective aperture. **(06 Marks)**

Module-4

7 a. Plot the field pattern for an array of 2 isotropic sources with equal amplitude and same phase. Take $d = \lambda/2$. (07 Marks)

b. Find Directivity of a source with a sine squared pattern (doughnut) (power pattern). (07 Marks)

c. State and explain power theorem. (06 Marks)

OR

8 a. Obtain the field pattern for a linear uniform array of isotropic antennas for $n = 6$, $d = \frac{\lambda}{2}$, $\partial = -d$, (08 Marks)

b. Obtain an expression for radiation resistance of a short dielectric dipole. (06 Marks)

c. Define and explain the principle of pattern multiplication. (06 Marks)

Module-5

9 a. From fundamentals obtain the radiation resistance of a small loop antenna. (08 Marks)

b. For a horn antenna, explain the horn antenna optimum dimensions. Explain with an example. (06 Marks)

c. Explain the principle of working of a parabolic Reflector antenna. (06 Marks)

OR

10 a. Define helix geometry. Explain the practical design considerations for the monoflex axial mode helical antenna. (06 Marks)

b. Explain the principle of a Yagi Uda Array Antenna. (08 Marks)

c. Calculate the directivity of a horn antenna with $a_e\lambda = 10\lambda$ $a_H = 9\lambda$. (06 Marks)

* * * * *

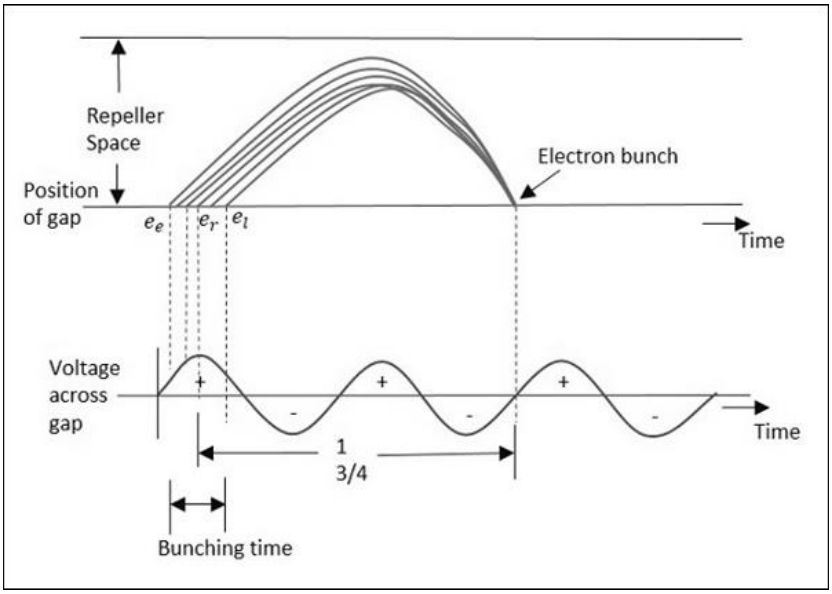
Scheme & Solution-VTU-QP

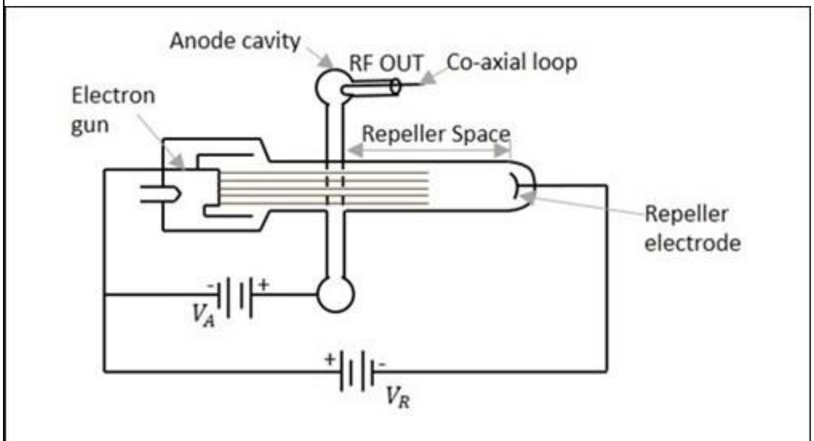
VTU Question Paper– Jan/Feb. 2022

Sub:	Microwaves and Antennas					Sub Code:	17EC71	Branch:	ECE
Date:	16-02-22	Duration:	90 Minutes	Max Marks:	50	Sem / Sec:	7/A		OBE

	Answer any FIVE FULL Questions	MARKS	CO	RBT
1 (a)	**With neat diagram, explain the concept of reflex klystron.**	[10]	CO1	L2

Solution

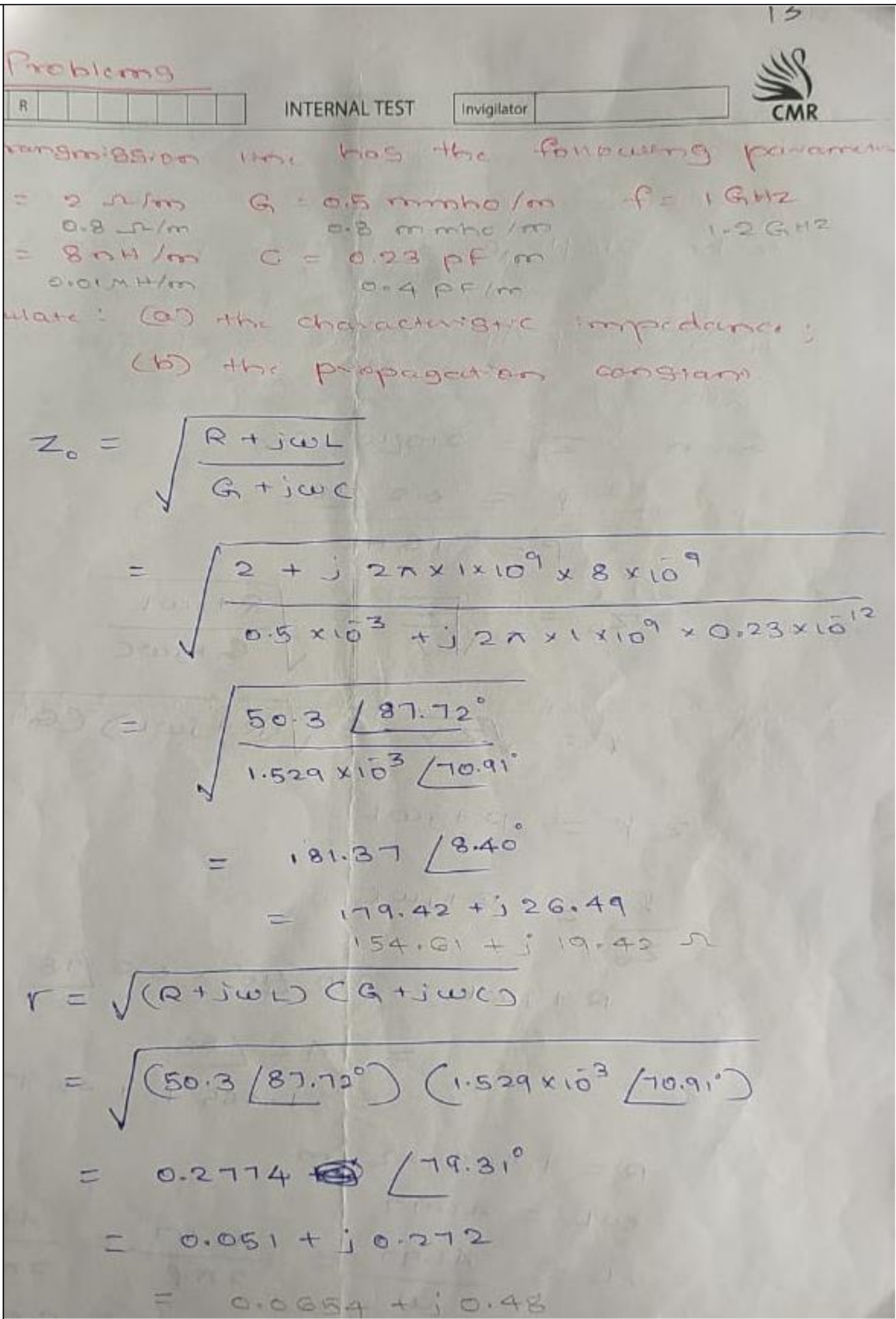




Constructional details of Reflex Klystron

	As with the multicavity klystron, the operating mechanism is best understood by considering the behavior of individual electrons. This time, however, the reference electron is taken as one that passes the gap on its way to the repeller at the time when the gap voltage is zero and going negative. This electron is of course unaffected, overshoots the gap, and is ultimately returned to it, having penetrated some distance into the repeller space. An electron passing the gap slightly earlier would have encountered a slightly positive voltage at the gap. The resulting acceleration would have propelled this electron slightly farther into the repeller space, and the electron would thus have taken a slightly longer time than the reference electron to return to the gap. Similarly, an electron passing the gap a little after the reference electron will encounter a slightly negative voltage. The resulting retardation will,shorten its stay in the repeller space. It is seen that, around the reference electron, earlier electrons take longer to return to the gap than later electrons, and so the conditions are right for bunching to take place. The situation can be verified experimentally by throwing a series of stones upward. If the earlier stones are thrown harder, i.e., accelerated more than the later ones, it is possible for all of them to come back to earth simultaneously, i.e., in a bunch. It is thus seen that, as in the multicavity klystron, velocity modulation is converted to current modulation in the repeller space, and one bunch is formed per cycle of oscillations. It should be mentioned that bunching is not nearly as complete in this case, and so the Reflex Klystron Oscillator is much less efficient than the multicavity klystron.			

1 (c)	**Define VSWR.** **<u>Solution</u>** VSWR is defined as the ratio of the maximum voltage to the minimum voltage in standing wave pattern along the length of a transmission line structure. It varies from 1 to (plus) infinity and is always positive. Unless you have a piece of slotted line-test equipment this is a hard definition to use, especially since the concept of voltage in a microwave structure has many interpretations. Sometimes VSWR is called SWR to avoid using the term voltage and to instead use the concept of power waves. This in turn leads to a mathematical definition of VSWR in terms of a reflection coefficient. A reflection coefficient is defined as the ratio of reflected wave to incident wave at a reference plane. This value varies from -1 (for a shorted load) to +1 (for an open load), and becomes 0 for matched impedance load. It is a complex number. This helps us because we can actually measure power. The reflection coefficient, commonly denoted by the Greek letter gamma (Γ), can be calculated from the values of the complex load impedance and the transmission line characteristic impedance which in principle could also be a complex number. $\Gamma = (Z_l - Z_0)/(Z_l + Z_0)$ The square of $\| \Gamma \|$ is then the power of the reflected wave, the square hinting at a historical reference to voltage waves. Now we can define VSWR (SWR) as a scalar value: VSWR= $(1 + \| \Gamma \|)/(1 - \| \Gamma \|)$ or in terms of s-parameters: VSWR= $(1 + \| S_{11} \|)/(1 - \| S_{11} \|)$	[04]	CO1	L1
2 (a)	**Obtain the transmission line equations from fundamentals.** **<u>Solution to Q.2a</u>**	[10]	CO1	L1
2 (b)		[04]	CO1	L2



13

Problems

R | INTERNAL TEST | Invigilator | CMR

...ransmission line has the following param...

= 2 Ω/m   G = 0.5 mmho/m   f = 1 GHz

0.8 Ω/m   0.8 mmho/m   1.2 GHz

= 8 nH/m   C = 0.23 pF/m

0.01 mH/m   0.4 pF/m

...ulate: (a) the characteristic impedance;

(b) the propagation constant

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$= \sqrt{\frac{2 + j\, 2\pi \times 1 \times 10^9 \times 8 \times 10^{-9}}{0.5 \times 10^{-3} + j\, 2\pi \times 1 \times 10^9 \times 0.23 \times 10^{-12}}}$$

$$= \sqrt{\frac{50.3 \angle 87.72^\circ}{1.529 \times 10^{-3} \angle 70.91^\circ}}$$

$$= 181.37 \angle 8.40^\circ$$

$$= 179.42 + j\, 26.49$$

$$154.61 + j\, 19.42\ \Omega$$

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$$

$$= \sqrt{(50.3 \angle 87.72^\circ)(1.529 \times 10^{-3} \angle 70.91^\circ)}$$

$$= 0.2774 \angle 79.31^\circ$$

$$= 0.051 + j\, 0.272$$

$$= 0.0654 + j\, 0.48$$

2 (c)	A Smith chart is **developed by examining the load where the impedance must be matched**. Instead of considering its impedance directly, you express its reflection coefficient L, which is used to characterize a load (such as admittance, gain, and trans conductance). The L is more useful when dealing with RF frequencies.	[06]	CO2	L2

3 and 4	**Solution to question 3 and 4**	[10]	CO2	L1, L2

5	**Example 11-1-1: Characteristic Impedance of Microstrip Line**	[10]	CO2	L1, L2

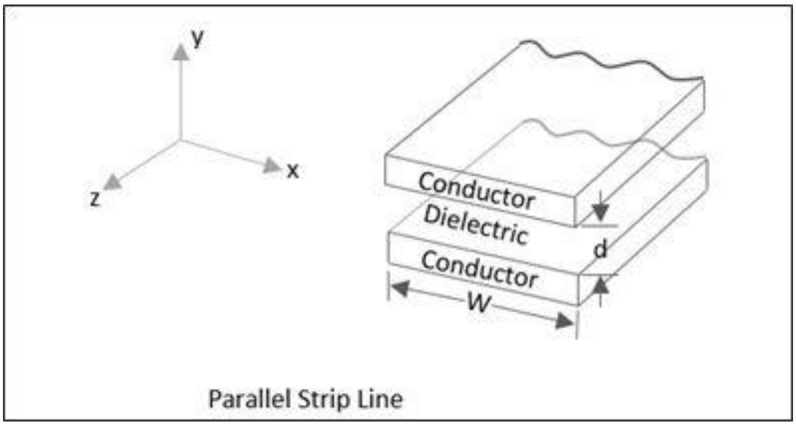
A certain microstrip line has the following parameters:

$\epsilon_r = 5.23$
$h = 7$ mils
$t = 2.8$ mils
$w = 10$ mils

Calculate the characteristic impedance Z_0 of the line.

Solution

$$Z_0 = \frac{87}{\sqrt{\epsilon_r + 1.41}} \ln\left[\frac{5.98h}{0.8w + t}\right]$$
$$= \frac{87}{\sqrt{5.23 + 1.41}} \ln\left[\frac{5.98 \times 7}{0.8 \times 10 + 2.8}\right]$$
$$= 45.78\ \Omega$$



Parallel Strip Line

11-2-1 Distributed Parameters

In a microwave integrated circuit a strip line can be easily fabricated on a dielectric substrate by using printed-circuit techniques. A parallel stripline is similar to a two-conductor transmission line, so it can support a quasi-TEM mode. Consider a TEM-mode wave propagating in the positive z direction in a lossless strip line ($R = G = 0$). The electric field is in the y direction, and the magnetic field is in the x direction. If the width w is much larger than the separation distance d, the fringing capacitance is negligible. Thus the equation for the inductance along the two conducting strips can be written as

$$L = \frac{\mu_c d}{w} \qquad \text{H/m} \qquad (11\text{-}2\text{-}1)$$

where μ_c is the permeability of the conductor. The capacitance between the two conducting strips can be expressed as

$$C = \frac{\epsilon_d w}{d} \qquad \text{F/m} \qquad (11\text{-}2\text{-}2)$$

where ϵ_d is the permittivity of the dielectric slab.

If the two parallel strips have some surface resistance and the dielectric substrate has some shunt conductance, however, the parallel stripline would have some losses. The series resistance for both strips is given by

$$R = \frac{2R_s}{w} = \frac{2}{w}\sqrt{\frac{\pi f \mu_c}{\sigma_c}} \qquad \Omega/\text{m} \qquad (11\text{-}2\text{-}3)$$

where $R_s = \sqrt{(\pi f \mu_c)/\sigma_c}$ is the conductor surface resistance in Ω/square and σ_c is the conductor conductivity in ℧/m. The shunt conductance of the strip line is

$$G = \frac{\sigma_d w}{d} \qquad ℧/\text{m} \qquad (11\text{-}2\text{-}4)$$

where σ_d is the conductivity of the dielectric substrate.

<table>
<tr>
<td>5

and

6</td>
<td>

Solutions to 5c and 6C

6a

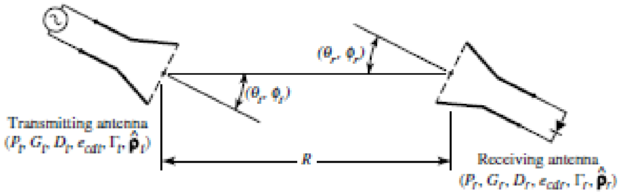
2.17 FRIIS TRANSMISSION EQUATION AND RADAR RANGE EQUATION

The analysis and design of radar and communications systems often require the use of the *Friis Transmission Equation* and the *Radar Range Equation*. Because of the importance [21] of the two equations, a few pages will be devoted for their derivation.

2.17.1 Friis Transmission Equation

The Friis Transmission Equation relates the power received to the power transmitted between two antennas separated by a distance $R > 2D^2/\lambda$, where D is the largest dimension of either antenna. Referring to Figure 2.31, let us assume that the transmitting antenna is initially isotropic. If the input power at the terminals of the transmitting antenna is P_t, then its isotropic power density W_0 at distance R from the antenna is

$$W_0 = e_t \frac{P_t}{4\pi R^2} \qquad \text{(2-113)}$$



</td>
<td></td>
<td></td>
<td></td>
</tr>
</table>

	where e_t is the radiation efficiency of the transmitting antenna. For a nonisotropic transmitting antenna, the power density of (2-113) in the direction θ_t, ϕ_t can be written as $$W_t = \frac{P_t G_t(\theta_t, \phi_t)}{4\pi R^2} = e_t \frac{P_t D_t(\theta_t, \phi_t)}{4\pi R^2} \quad (2\text{-}114)$$ where $G_t(\theta_t, \phi_t)$ is the gain and $D_t(\theta_t, \phi_t)$ is the directivity of the transmitting antenna in the direction θ_t, ϕ_t. Since the effective area A_r of the receiving antenna is related to its efficiency e_r and directivity D_r by $$A_r = e_r D_r(\theta_r, \phi_r)\left(\frac{\lambda^2}{4\pi}\right) \quad (2\text{-}115)$$ the amount of power P_r collected by the receiving antenna can be written, using (2-114) and (2-115), as $$P_r = e_r D_r(\theta_r, \phi_r)\frac{\lambda^2}{4\pi} W_t = e_t e_r \frac{\lambda^2 D_t(\theta_t, \phi_t) D_r(\theta_r, \phi_r) P_t}{(4\pi R)^2} \lvert \hat{\rho}_t \cdot \hat{\rho}_r \rvert^2 \quad (2\text{-}116)$$ or the ratio of the received to the input power as $$\boxed{\frac{P_r}{P_t} = e_t e_r \frac{\lambda^2 D_t(\theta_t, \phi_t) D_r(\theta_r, \phi_r)}{(4\pi R)^2}} \quad (2\text{-}117)$$ The power received based on (2-117) assumes that the transmitting and receiving antennas are matched to their respective lines or loads (reflection efficiencies are unity) and the polarization of the receiving antenna is polarization-matched to the impinging wave (polarization loss factor and polarization efficiency are unity). If these two factors are also included, then the ratio of the received to the input power of (2-117) is represented by $$\boxed{\frac{P_r}{P_t} = e_{cdt} e_{cdr}(1 - \lvert\Gamma_t\rvert^2)(1 - \lvert\Gamma_r\rvert^2)\left(\frac{\lambda}{4\pi R}\right)^2 D_t(\theta_t, \phi_t) D_r(\theta_r, \phi_r) \lvert \hat{\rho}_t \cdot \hat{\rho}_r \rvert^2} \quad (2\text{-}118)$$ For reflection and polarization-matched antennas aligned for maximum directional radiation and reception, (2-118) reduces to $$\boxed{\frac{P_r}{P_t} = \left(\frac{\lambda}{4\pi R}\right)^2 G_{0t} G_{0r}} \quad (2\text{-}119)$$			
7	**Solutions to question no. 7 and 8a**			
8 and 9	**Solution to Q. 8 and 9**			
10	**Solution to Q. 10**			