CBCS SCHEME

USN | | | | | | | | | | 15EC71

Seventh Semester B.E. Degree Examination, July/August 2021
Microwave and Antennas

Time: 3 hrs. Max. Marks: 80

Note: ***Answer any FIVE full questions.***

1 a. Derive the general transmission line equation to find voltage and current on the line interms of position 'z' and time 't'. **(08 Marks)**
b. With a neat diagram, explain the operation of Reflex Klystron. **(08 Marks)**

2 a. Define transmission coefficient. Derive the equation for transmission coefficient of power transmission line. **(08 Marks)**
b. A transmission line has a characteristic impedance of $75 + j0.01\Omega$ and is terminated in a load impedance of $70 + j50\Omega$. Compute :
i) Reflection coefficient
ii) Transmission coefficient
iii) Verify relation between reflection and transmission coefficient
iv) Verify $T = 1 + \Gamma$. **(08 Marks)**

3 a. Explain non-reciprocal phase shifter with a neat diagram. **(08 Marks)**
b. In an H-plane T-junction, compute power delivered to the loads of 40Ω and 60Ω connected to arms 1 and 2 when a 10mw power is delivered to the matched port 3. **(08 Marks)**

4 a. What are waveguide tees? Explain its types. **(08 Marks)**
b. Briefly explain the applications of Magic – T. **(08 Marks)**

5 a. Explain the losses in microstrip lines. **(08 Marks)**
b. A lossless parallel strip line has a conducting strip width w. the substrate dielectric constant $\in_{rd}$ of 6 (BeO) and a thickness 'd' of 4mm. Calculate :
i) Width w of the strip to have a characteristic impedance of 50Ω
ii) Strip-line capacitance
iii) Strip-line inductance
iv) Phase velocity of wave in parallel strip line. **(08 Marks)**

6 a. Define directivity. Derive the relation between :
i) Directivity and beam solid angle
ii) Directivity and effective aperture. **(08 Marks)**
b. Show that maximum effective aperture of $\lambda/2$ dipole (Aem) = $0.13\lambda^2$ and Directivity = 1.63. **(08 Marks)**

7 a. Derive an expression and draw the field pattern for an array of two isotropic point sources with equal amplitude and opposite phase. **(08 Marks)**

b. Find the power and directivity of :

i) $U = U_m \sin^2\theta$ for $0 \le \theta \le \pi$; $0 \le \phi \le 2\pi$

ii) $U = U_m \cos^2\theta$ for $0 \le \theta \le \pi/2$; $0 \le \phi \le 2\pi$. **(08 Marks)**

8 a. Derive the radiation resistance of thin $\lambda/2$ antenna. **(08 Marks)**

b. Explain :

i) Power theorem

ii) Multiplication pattern. **(08 Marks)**

9 a. Derive the radiation resistance of small loop. **(08 Marks)**

b. Explain in brief with neat figure.

i) Horn Antenna

ii) Yagi Uda Antenna. **(08 Marks)**

10 a. With neat diagram, explain the following

i) Log periodic antenna

ii) Helical antenna. **(08 Marks)**

b. Find the directivity, beam width and effective area of the parabolic reflector for which the reflector diameter is 6m and apperature efficiency is 0.65. The frequency of operation is 10GHz. **(08 Marks)**

* * * * *

Visvesvaraya Technological University
Belagavi, Karnataka - 590 018

190915EC7114074

Signature of Scrutinizer

Scheme & Solution

Subject Title : Microwave & Antennas **Subject Code :** 15EC71

Question Number	Solution	Marks Allocated
	Module - 1	

1 a] Solutions of Transmission - Line equations.

WKT $\frac{d^2V}{dz^2} = \gamma^2 V \rightarrow (1)$

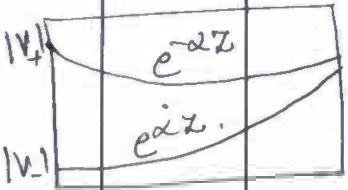
(2M)

$V = V_+ e^{-\gamma z} + V_- e^{\gamma z} = V_+ e^{-\alpha z} e^{-j\beta z} + V_- e^{\alpha z} e^{j\beta z} \rightarrow (2)$

$I = Y_0 (V_+ e^{-\gamma z} - V_- e^{\gamma z}) = Y_0 (V_+ e^{-\alpha z} e^{-j\beta z} - V_- e^{\alpha z} e^{j\beta z}) \rightarrow (3)$

$\beta z \rightarrow$ electrical length in radians.

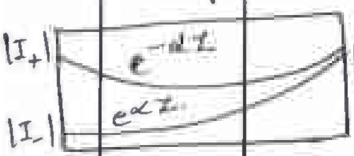
From eqn (3) $Z_0 = \frac{1}{Y_0} = \sqrt{\frac{Z}{Y}} = \sqrt{\frac{R+j\omega L}{G+j\omega C}} = R_0 \pm jX_0 \rightarrow (4)$



voltage wave

At microwave frequencies $R \ll \omega L$ and $G \ll \omega C$

$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)} = \sqrt{(j\omega)^2 LC}\sqrt{\left(1+\frac{R}{j\omega L}\right)\left(1+\frac{G}{j\omega C}\right)}$



current wave

(4M)

$\gamma = \frac{1}{2}\left(R\sqrt{\frac{C}{L}} + G\sqrt{\frac{L}{C}}\right) + j\omega\sqrt{LC} \rightarrow (5)$

$\alpha = \frac{1}{2}\left[R\sqrt{\frac{C}{L}} + G\sqrt{\frac{L}{C}}\right]$ & $\beta = \omega\sqrt{LC} \rightarrow (6)$

$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}} = \sqrt{\frac{L}{C}}\left(1+\frac{R}{j\omega L}\right)^{1/2}\left(1+\frac{G}{j\omega C}\right)^{-1/2} = \sqrt{\frac{L}{C}} \rightarrow (7)$

$v_p = \frac{\omega}{\beta} = \frac{1}{\sqrt{LC}} \rightarrow (8) = 3\times10^8$ m/s $V_e = \frac{c}{\sqrt{\mu_r \epsilon_r}}$ $V_R = \frac{V_e}{c} = \frac{1}{\sqrt{\mu_r \epsilon_r}}$ $\rightarrow$ (2M)

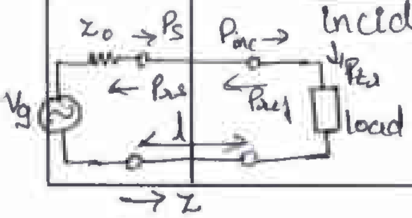
[2+4+2] = 8M

Marks Allocated: [2+4+2] (8M)

1b] Neat figure $\rightarrow$ (3M) Expl^n $\rightarrow$ (5M) = (2M+3M)
[Description and mechanism of oscillation]
[3+5] = 8M

Marks Allocated: [3+5] (8M)

2 a] $T = \frac{\text{transmitted vtg or current}}{\text{incident vtg or current}} = \frac{V_{tr}}{V_{inc}} = \frac{I_{tr}}{I_{inc}} \rightarrow$ (1M)



$V_+ e^{-\gamma l} + V_- e^{\gamma l} = V_{tr} e^{-\gamma l}$
$\frac{V_+}{Z_0} e^{-\gamma l} - \frac{V_-}{Z_0} e^{\gamma l} = \frac{V_{tr}}{Z_l} e^{-\gamma l}$ $\rightarrow (1)$

(3M)

Marks Allocated: [1+3+4] (8M)

Subject Title : Microwave & Antennas **Subject Code :** 15EC71

Question Number	Solution	Marks Allocated
	$T = \frac{V_{tr}}{V_+} = \frac{2Z_l}{Z_l+Z_0} \rightarrow (2)$ $P_{inr} = P_{inc} - P_{ref} = \frac{(V_+ e^{-\alpha l})^2 - (V_- e^{\alpha l})^2}{2Z_0}$	$\rightarrow (3)$
	$P_{tr} = \frac{(V_{tr} e^{-\alpha l})^2}{2Z_l}$, But $P_{inr} = P_{tr}$ so $T^2 = \frac{Z_l}{Z_0}(1-\Gamma_l^2) \rightarrow (4) \rightarrow$ 4M $[1+3+4] = 8M$	
2b	Solⁿ: $Z_0 = 75 + j0.01\Omega$ $Z_l = 70 + j50\Omega$	
a)	$\Gamma = \frac{Z_l - Z_0}{Z_l - Z_0} = \frac{(70+j50\Omega) - (75+j0.01)}{(70+j50)+(75+j0.01)} = \frac{50.24 \angle 95.71^\circ}{153.38 \angle 19.03^\circ}$ $\Gamma = 0.33 \angle 76.68^\circ = 0.08 + j0.32 \rightarrow$ 2M	
b)	$T = \frac{2Z_l}{Z_l + Z_0} = \frac{172.05 \angle 35.54^\circ}{153.38 \angle 19.03^\circ} = 1.08 + j0.32 \rightarrow$ 2M	$[2+2+2+2]$ 8M
c)	$T^2 = 1.25 \angle 33.02^\circ$; $\frac{Z_l}{Z_0}(1-\Gamma^2) = 1.25 \angle 33.02^\circ$ $\therefore T^2 = \frac{Z_l}{Z_0}(1-\Gamma^2) \longrightarrow$ 2M	
d)	$T = 1 + \Gamma = 1.08 + j0.32 = 1 + 0.08 + j0.32 \rightarrow$ 2M $[2+2+2+2] = 8M$	
	Module-2	
3a)	Fig: 3M Explⁿ: – 5M $[3+5] = 8M$	$[3+5]$ 8M
3b)	Solⁿ: Port 3 matched, [S] for H-plane T is $[S] = \frac{1}{2}\begin{bmatrix} -1 & 1 & \sqrt{2} \\ 1 & -1 & \sqrt{2} \\ \sqrt{2} & \sqrt{2} & 0 \end{bmatrix}$ Port 3 = 10mW ; $Z_1 = 40\Omega$ & $Z_2 = 60\Omega$ Reflected power to load Z_1 & Z_3 are	$[1+3+2+2]$ 8M
1M	$P_1 = \frac{1}{2}\lvert b_1\rvert^2 - \frac{1}{2}\lvert\Gamma_1 b_1\rvert^2 = \frac{1}{2}\lvert b_1\rvert^2(1-\lvert\Gamma_1\rvert^2)$ $P_2 = \frac{1}{2}\lvert b_2\rvert^2 - \frac{1}{2}\lvert\Gamma_2 b_2\rvert^2 = \frac{1}{2}\lvert b_2\rvert^2(1-\lvert\Gamma_2\rvert^2)$ } 3M	
$\lvert\Gamma_1\rvert$	$= 1/9$ & $\lvert\Gamma_1\rvert^2 = 0.0123$; $\lvert\Gamma_2\rvert = 1/11$ & $\lvert\Gamma_2\rvert^2 = 8.3\times10^{-3}$ $\therefore P_1 = 4.9383$ mV & $P_2 = 0.005(1-\lvert\Gamma_2\rvert^2)$ $P_1 = 0.005[1-\lvert\Gamma_1\rvert^2]$ $= 0.005(1-8.2694\times10^{-3})$ $P_2 = 4.9586$ mW	

2M $\rightarrow P_1 = 4.9383$ mW $\rightarrow$ 2M

Subject Title : Microwave & Antennas **Subject Code :** 15EC71

Question Number	Solution	Marks Allocated
4a]	Waveguide tees are 3-port components, used to connect a branch or section of the waveguide in series/parallel with main transmission line to provide splitting and combining power of waveguide. Types : E-plane T and H-plane T → 2M fig : → 2M Expl^n → 3M [2+3+3] = 8M	[2+3+3] 8M
4b]	Applications of magic-T are 1) E-H Tuner : fig → 2M Expl^n → 2M [4+4] = 8M 2) Balanced Mixer : fig → 2M Expl^n → 2M	[4+4] 8M
	Module - 3	
5a]	Losses in microstrip :* Dielectric loss * Ohmic loss → 2M * Radiation losses $\alpha_d = \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}}$, $q = \frac{\varepsilon_{re}-1}{\varepsilon_r-1}$ $\boxed{\alpha_d = 27.3\left(\frac{q\varepsilon_r}{\varepsilon_{re}}\right)\frac{\tan\theta}{\lambda_g}}$ → 2M $R_s = \sqrt{\pi f \mu/\sigma}$ $R_s = \frac{1}{\delta\sigma}\ \Omega/sq$ $\delta = \sqrt{\frac{1}{\pi f \mu \sigma}}$ skin depth. → 2M $R_r = 240\pi^2\left[\frac{h}{\lambda_0}\right]^2 F(\varepsilon_{re})$ → 2M [2+2+2+2] = 8M	[2+2+2+2] 8M
5b]	Sol^n : $\varepsilon_{rd} = 6$ $d = 4mm$ a] $Z_0 = \sqrt{\frac{L}{C}} = \frac{d}{w}\sqrt{\frac{\mu_d}{\varepsilon_d}} = \frac{377}{\sqrt{\varepsilon_{rd}}}\frac{d}{w}$ $\therefore w = 12.31\times10^{-3}\ m$ b] $C = \frac{\varepsilon_d W}{d} = 163.50\ pF/m$ c] $L = \frac{\mu_c d}{W} = 0.41\ \mu H/m$ d] $v_p = \frac{c}{\sqrt{\varepsilon_{rd}}} = \frac{3\times10^8}{\sqrt{6}} = 1.22\times10^8\ m/s$ [2M each] [2M×4] = 8M	[2+2+2+2] 8M

4076

Subject Title : Microwave & Antennas **Subject Code :** 15EC71

Question Number	Solution	Marks Allocated

[Or]

6 a]

$$D = \frac{U(\theta,\phi)_{max}}{U(\theta,\phi)_{avg}} \rightarrow (1M)$$

i] Directivity & solid beam angle

$$D = \frac{P_m(\theta,\phi)}{P_{avg}(\theta,\phi)} \;;\; P_{avg} = \frac{1}{4\pi}\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} P(\theta,\phi)\,d\Omega = \frac{1}{4\pi}\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} P(\theta,\phi)\sin\theta\, d\theta\, d\phi \rightarrow (1M)$$

$$D = \frac{4\pi P_m(\theta,\phi)}{\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} P(\theta,\phi)\sin\theta\, d\theta\, d\phi} \rightarrow \boxed{D = \frac{4\pi}{\Omega_A}} \rightarrow (2M)$$

ii] Directivity & Effective aperture [2+2+2+2] = 8M

$P = \frac{V^2}{Z} \rightarrow (1)$, $E_a = V/m$, $E_a^2 = V^2/m^2$, $V^2 = E_a^2 m^2 = E_a^2 A \rightarrow (2)$

$P = \frac{E_a^2 A}{Z} \rightarrow (3)$, $P = \frac{E_r^2 r^2 \Omega_A}{Z} \rightarrow (4)$, $E_r = \frac{E_a A}{r\lambda} \rightarrow (5) \rightarrow (2M)$

Equate eqn (3) & (4) $\frac{E_a^2 A}{\cancel{Z}} = \frac{E_a^2 A^2 \cancel{r^2} \Omega_A}{\cancel{r^2}\lambda^2 \cancel{Z}}$ $\therefore A = \frac{\lambda^2}{\Omega_A}$, $\lambda^2 = \Omega_A A \rightarrow (6)$

$\lambda^2 = \Omega_A A_{em} \rightarrow (7)$, $D = \frac{4\pi}{\Omega_A}$, $\Omega_A = \frac{4\pi}{D} \rightarrow (8)$

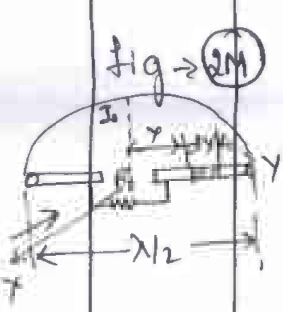
$\therefore \boxed{D = \frac{4\pi}{\lambda^2}\cdot A_{em}} \rightarrow (2M)$

[1+1+2+2+2] 8M

6 b]

$A_{em} = 0.13\lambda^2$ & $D = 1.63$

fig $\rightarrow$ (2M)



$I = I_0 \cos\beta y = I_0 \cos\left[\frac{2\pi y}{\lambda}\right]$, $E = \frac{V}{dy}$ $\therefore V = E\,dy$

$\int dV = \int_0^{\lambda/2} E\cos\left(\frac{2\pi y}{\lambda}\right) dy$, $\int dV = \frac{\lambda E}{\pi}$ $\therefore V = \frac{\lambda E}{\pi}$ [2+4+2]

w.k.t $A_{em} = \frac{V^2}{4SR_r}$, $S = \frac{P}{A}$, $P = \frac{E^2}{Z}\cdot A$ 8M

$A_{em} = \frac{30\lambda^2}{73\pi} = \boxed{A_{em} = 0.13\lambda^2} \rightarrow (4M)$ $D = \frac{4\pi}{\lambda^2}\cdot A_{em}$

$(2M) \rightarrow \boxed{D = 1.63}$

[2+4+2] = 8M

Module 4

7 a]

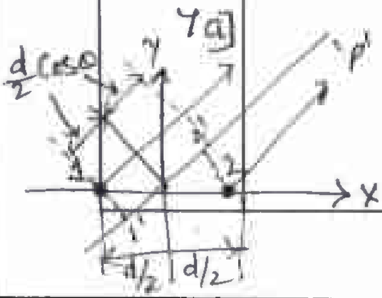


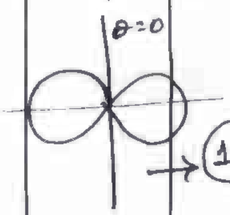
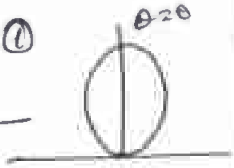
fig $\rightarrow$ (2M) Path diff = $\frac{d}{\lambda}\cos\theta$, $\psi = 2\pi\left[\frac{d}{\lambda}\cos\theta\right]$

$\psi = \beta d\cos\theta$

$E = -E_1 e^{-j\psi/2} + E_2 e^{j\psi/2}$ $E_{nor} = \left[\sin \frac{\pi}{2}\cos\theta\right] \rightarrow (2M)$

$E = 2E_0\left[\frac{e^{j\psi/2} - e^{-j\psi/2}}{2}\right]$ Maxima: $\theta_{max} = 0°$ or $180° \rightarrow (1M)$

Subject Title : Microwave & Antennas **Subject Code :** 15EC71

Question Number	Solution	Marks Allocated
	Minima : $\theta_{min} = 90°$ or $270°$ & HPP : $\theta_{HPP} = 60°$ or $120° \rightarrow$ (2M) field pattern — End fire $\rightarrow$ (2M) $[1+2+1+2+2] = 8M$	[1+2+1+2+2] (8M)
7b	i] $U = U_m \sin^2\theta$, $P = U_m \int_0^{\pi}\int_0^{2\pi} \sin^3\theta \, d\theta \, d\phi = \frac{8}{3}\pi U_m \rightarrow ①$ Isotropic $P = 4\pi U_0 \rightarrow ②$ Equate ① + ② $P = \frac{8}{3}\pi U_m = 4\pi U_0$ $D = \frac{U_m}{U_0} = \underline{1.5} \rightarrow$ (3M)  $\theta=0$ $\rightarrow$ (1M) ii] $U = U_m \cos^2\theta$, $P = U_m \int_0^{2\pi}\int_0^{\pi/2} \cos^2\theta \sin\theta \, d\theta \, d\phi$ P for isotropic $= 4\pi U_0 \rightarrow ②$ $P = \frac{2}{3}\pi U_m \rightarrow ①$ Equate ① + ② $\frac{2}{3}\pi U_m = 4\pi U_0$  $\theta=0$ (1M) $D = \frac{U_m}{U_0} = \underline{6} \rightarrow$ (3M) $[3+1+3+1] = 8M$	[3+1+3+1] (8M)
8a	Radiation Resistance of $\lambda/2$ antenna $P = \left[\frac{I_0}{\sqrt{2}}\right]^2 R_0$, $E_\theta = H_\phi Z = H_\phi \sqrt{\frac{\mu}{\varepsilon}}$, $P = \iint S_r \, ds = \frac{1}{2}\sqrt{\frac{\mu}{\varepsilon}} \int_0^{2\pi}\int_0^{\pi} \lvert H_\phi \rvert^2 r^2 \, ds \rightarrow ①$ $P = \frac{15 I_0^2}{\pi} \int_0^{2\pi}\int_0^{\pi} \frac{[\cos[(\beta L/2)\cos\theta] - \cos(\beta L/2)]^2}{\sin\theta} d\theta \rightarrow ② \rightarrow$ (2M) $P = 30 I_0^2 \int_0^{\pi} \frac{[\cos[(\beta L/2)\cos\theta] - \cos(\beta L/2)]^2}{\sin\theta} d\theta \rightarrow ③$, $P = \frac{I_0^2 R_0}{2}$ $R_0 = 60 \int_0^{\pi} \frac{\{\cos[(\beta L/2)\cos\theta] - \cos(\beta L/2)\}^2}{\sin\theta} d\theta \rightarrow$ (2M) $R_r = 30 \, Cin(2\pi) = 30 \times 2.44 = \underline{73\,\Omega}$ $\boxed{R_r = 73\,\Omega} \rightarrow$ (2M) $\boxed{Z = 73 + j42.5\,\Omega} \rightarrow$ (1M) $[2+3+2+1] = 8M$	[2+3+2+1] (8M)
8b	State & Expl^n power theorem $\rightarrow$ (4M) State principle of multiplication pattern with Ex: $\rightarrow$ (4M) $[4+4] = 8M$	[4+4] (8M)
	Module – 5	
9a	Radiation resistance of small loop $P = \frac{I_0^2}{2} R_r$, $S_r = \frac{1}{2} \lvert H \rvert^2 Re Z$, $H_\theta = \frac{\beta a [I]}{2r} J_1[\beta a \sin\theta]$ $\rightarrow$ (2M)	

Q.No.		Marks
	$S_r = \frac{15\pi(\beta a I_0)^2}{r^2} J_1^2(\beta a \sin\theta)$, Total power over a sphere $P = \iint S_r\, ds = 15\pi(\beta a I_0)^2 \int_0^{2\pi}\int_0^{\pi} J_1^2(\beta a \sin\theta)\sin\theta\, d\theta\, d\phi$ $P = 30\pi^2(\beta a I_0)^2 \int_0^{\pi} J_1^2(\beta a \sin\theta)\sin\theta\, d\theta \rightarrow$ 2M $P = \frac{15}{2}\pi^2(\beta a)^4 I_0^2 \int_0^{\pi} \sin^3\theta\, d\theta = 10\pi^2\beta^4 a^4 I_0^2$ But $A = \pi a^2$ $P = 10\beta^4 A^2 I_0^2$, $R_r \frac{I_0^2}{2} = 10\beta^4 A^2 I_0^2 \rightarrow$ 2M $\therefore R_r = 31171\left[\frac{A}{\lambda^2}\right]^2 \Omega$ or $31200\left[\frac{A}{\lambda^2}\right]^2 \Omega \rightarrow$ 2M [2+2+2+2]=8M	[2+2+2+2] 8M
9b	i] fig → 2M Expl^n → 2M ii] fig → 2M Expl^n → 2M	[4+4] 8M
10a	i] Neat fig → 2M Expl^n → 2M ii] Neat fig → 2M Expl^n → 2M	[4+4] 8M
10b	Sol^n: $d = 6m$, $\epsilon = 0.65$, $f = 10$ GHz. Aperture efficiency, $\epsilon = \frac{A_e}{A_p}$, $0.65 = \frac{A_e}{(\pi d^2/4)}$ $\therefore A_e = 18.38\, m^2$ 2M wkt $\lambda = \frac{c}{f} = \frac{3\times10^8}{10\times10^9} = 0.03m \rightarrow$ 1M $HPBW = \frac{BWFN}{2} = \frac{140\lambda}{d\times2}$ $D = \frac{4\pi}{\lambda^2} \cdot A_e = 256605.28$ $HPBW = 0.35^\circ \rightarrow$ 2½ M $D = 54.09$ dB → 2½ M $[2 + 1 + 2½ + 2½] = 8M$.	[2+1+2½+2½] 8M

—— xxxx ——