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Electronics and Communication Engineering Department

Microwave Engineering (ECE)

Date:26/02/2018 Mid Term- 2018 Class Size:199 R

Time : 1.5Hrs Full Marks 50

	CO1	CO2	CO3	CO4	CO5
Questions	1,2,3	4,5,6	-	-	-
Marks	28	22	-	-	-
Marks/Max Marks (%)	56	44	-	-	-

Answer must be brief and to the point. Symbols have their usual meaning. All parts of the question must be answered in sequence.

Q1. a) Why conventional vacuum tubes are less useful signal sources above 1 GHz? **List** at least 4 reasons.
b) Mention the IEEE Microwave frequency bands with frequency range from HF to $K_a$band.
c) Show the Linear beam Tubes (O Type) classification.

[3+3+2=8]

Q2. a) What is velocity modulation? Draw Applegate diagram for Two Cavity Klystron.
b) Starting from velocity modulation equation prove that the necessary condition to meet electrons at the same distance (ΔL) from buncher grid is

$$t_d - t_b = \frac{\pi V_0}{\omega \beta_i V_1}$$

c) A two cavity klystron amplifier is tuned at 3 GHz. The drift space length is 2 cm, beam current 25 mA. The catcher voltage is 0.3 times the beam voltage. It is assumed that the gap length of the cavity << the drift space, so that the input and output voltages are in phase ($\beta = 1$). Compute (i) Beam voltage, Buncher and Catcher voltage for $N = 5\frac{1}{4}$ (ii) Power output and efficiency for $N = 5\frac{1}{4}$

[(1+2)+4+(3+2)=12]

Q3. a) Using the principle of charge conservation prove that in two cavity klystron current arriving at catcher cavity at time t_2 is given by

$$i_2(t_2) = \frac{I_0}{1 - X\cos\left(\omega t_2 - \theta_0 - \frac{\theta_g}{2}\right)}$$

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b) Using the following formula prove that the theoretical maximum efficiency of two cavity klystron is 58%.

Given

$i_2 = a_0 + \sum_1^{\infty}[a_n \cos(n\omega t_2) + b_n \sin(n\omega t_2)]$where, $a_0 = I_0$

$a_n = 2I_0 J_1(nX)\cos(n\theta_g + n\theta_0)$,and $b_n = 2I_0 J_1(nX)\sin(n\theta_g + n\theta_0)$

$t_2 = t_0 + \tau + T_0[1 - \frac{\beta_i V_1}{2V_0}\sin\left(\omega t_0 + \frac{\theta_g}{2}\right)$ Also, $\omega T_0 = \theta_0$and bunching parameter $X = \frac{\beta_i V_1}{2V_0}\theta_0$

[4+4=8]

Q4. a). For an air-filled half-foot long WR90 rectangular waveguide (a=2.286 cm, b=1.016 cm), calculate the amount of phase-shift that this transmission line will introduce in a 9.7 GHz signal passing through it.

b). For an air-filled circular waveguide with 5 cm diameter, calculate the wave impedance at an operating frequency of 5.86 GHz.

[4+4=8]

Q5. Calculate the ABCD parameters and scattering parameters of a 30-mil wide microstrip line at 2.4 GHz frequency, assuming that the line length is 24 cm. Assume that the line is deposited on a 10-mil thick RT5880 substrate whose dielectric constant is 2.2. Neglect line losses.

[2+2+2+2=8]

OR

Calculate the ABCD parameters and scattering parameters of a 8-mil wide stripline at 2.4 GHz frequency, assuming that the line length is 24 cm. Assume that the line is deposited on a 10-mil thick RT5880 substrate whose dielectric constant is 2.2. Neglect line losses.

[2+2+2+2=8]

Q6. Design a L-section impedance-matching network to match a load whose impedance is 200 + j100 Ω to a 50-Ω transmission line at an operating frequency of 1000 MHz .

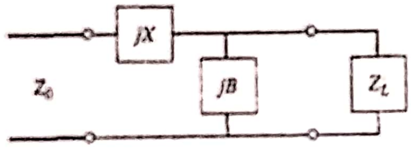
[6]

$$fc\,(TE_{11}) = (1.8412c)/(2\pi a)$$

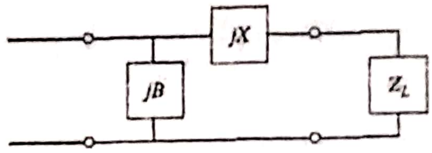
$$\frac{W}{b} = \begin{cases} \frac{30\pi}{\sqrt{\epsilon_r}Z_0} - 0.441 & \text{for } \sqrt{\epsilon_r}Z_0 < 120 \\ 0.85 - \sqrt{0.6 - (\frac{30\pi}{\sqrt{\epsilon_r}Z_0} - 0.441)} & \text{for } \sqrt{\epsilon_r}Z_0 > 120 \end{cases}$$

$$\frac{W_e}{b} = \frac{W}{b} - \begin{cases} 0 & \text{for } \frac{W}{b} > 0.35 \\ (0.35 - W/b)^2 & \text{for } \frac{W}{b} < 0.35 \end{cases}$$

$$Z_0 = \frac{30\pi}{\sqrt{\epsilon_r}} \frac{b}{W_e + 0.441b}$$



Network for z_L inside the 1+jx circle



Network for z_L outside the 1+jx circle

$$Z_0 = jX + \frac{1}{jB + 1/(R_L + jX_L)}$$

$$B(XR_L - X_L Z_0) = R_L - Z_0$$

$$X(1 - BX_L) = BZ_0 R_L - X_L$$

$$B = \frac{X_L \pm \sqrt{R_L/Z_0}\sqrt{R_L^2 + X_L^2 - Z_0 R_L}}{R_L^2 + X_L^2}$$

$$X = \frac{1}{B} + \frac{X_L Z_0}{R_L} - \frac{Z_0}{BR_L}$$

$$\frac{1}{Z_0} = jB + \frac{1}{R_L + j(X + X_L)}$$

$$BZ_0(X + X_L) = Z_0 - R_L$$

$$(X + X_L) = BZ_0 R_L$$

$$X = \pm\sqrt{R_L(Z_0 - R_L)} - X_L$$

$$B = \pm\frac{\sqrt{(Z_0 - R_L)/R_L}}{Z_0}$$

Positive X implies an inductor and negative X implies a capacitor
Positive B implies an capacitor and negative B implies a inductor

$$S_{11} = \frac{A + \frac{B}{Z_0} - CZ_0 - D}{A + \frac{B}{Z_0} + CZ_0 + D}$$

$$S_{22} = \frac{-A + \frac{B}{Z_0} - CZ_0 + D}{A + \frac{B}{Z_0} + CZ_0 + D}$$

$$S_{12} = \frac{2(AD - BC)}{A + \frac{B}{Z_0} + CZ_0 + D}$$

$$S_{21} = \frac{2}{A + \frac{B}{Z_0} + CZ_0 + D}$$

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Velocity modulation equation

$$v(t_1) = \sqrt{\frac{2e}{m}\left[V_0 + \beta_i V_1 \sin\left(\omega t_0 + \frac{\theta_g}{2}\right)\right]}$$

Beam Voltage

$$V_0 = \frac{m}{2e}(Lf/N)^2$$

$$e/m = 1.758820024 \times 10^{11}\ C/kg.$$

Bunching parameter for maximum output

$$X = 1.84 = \frac{\pi N V_1}{V_0}$$

Efficiency, $\eta = \frac{\beta_i V_2 J_1(X)}{V_0}$, Given $J_1(X) = 0.582\ for\ X = 1.841$

$$\epsilon_e = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\frac{1}{\sqrt{1 + 12d/W}}$$

$$Z_0 = \begin{cases} \frac{60}{\sqrt{\epsilon_e}} \ln\left(\frac{8d}{W} + \frac{W}{4d}\right) & \text{for } W/d \le 1 \\ \frac{120\pi}{\sqrt{\epsilon_e}[W/d + 1.393 + 0.667 \ln(W/d + 1.444)]} & \text{for } W/d \ge 1 \end{cases}$$

$$\frac{W}{d} = \begin{cases} \frac{8\, e^A}{e^{2A} - 2} & \text{for } W/d \le 2 \\ \frac{2}{\pi}\left[B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r}\left(\ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r}\right)\right] & \text{for } W/d \ge 2 \end{cases}$$

$$A = \frac{Z_0}{60}\sqrt{\frac{\epsilon_r + 1}{2}} + \frac{\epsilon_r - 1}{\epsilon_r + 1}\left(0.23 + \frac{0.11}{\epsilon_r}\right) \quad \text{and} \quad B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}}$$

1

SNR

$dBW = dBm - 30$

$\frac{P_s in}{P_N in} [G] \frac{P_s out}{P_N out}$

$1 Np = \frac{20}{\ln 10} = 8.686 dB$

$1 dB = \frac{\ln 10}{20} = 0.115 Np$

$\boxed{V = \sqrt{PR} = 774.6 mV}$

$\boxed{P_s out = G P_s in}$

$SNR = \frac{P_s}{P_N}$ $\boxed{P_N out = GK(T_{in} + T_e)B}$

$\boxed{SNR out = \frac{P_s in}{GKB(T_{in} + T_e)}}$

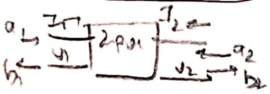
$SNR in = \frac{P_s in}{K T_{in} B}$

$F = \boxed{\frac{SNR in}{SNR out} = 1 + \frac{T_e}{T_{in}}}$ $P_s > P_N$

$f = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} \cdots$

$\boxed{N = 10 \log_{10}(F)}$

Two port network



$V_1 = Z_{11} I_1 + Z_{12} I_2$

$V_2 = Z_{21} I_1 + Z_{22} I_2$

$I_1 = Y_{11} V_1 + Y_{12} V_2$

$I_2 = Y_{21} V_1 + Y_{22} V_2$

Transmission para

$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$

Hybrid para

$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$

Scattering para

$b_1 = S_{11} a_1 + S_{12} a_2$

$b_2 = S_{21} a_1 + S_{22} a_2$

$V(x) = V^+(x) + V^-(x)$

$I(x) = \frac{V^+(x)}{Z_0} - \frac{V^-(x)}{Z_0}$

$a(x) = \frac{V^+(x)}{\sqrt{Z_0}}$ $b(x) = \frac{V^-(x)}{\sqrt{Z_0}}$

$P = \frac{1}{2} a a^*$ $P = \frac{1}{2} b b^*$

~~$V(x) = \frac{V^+(x)}{\sqrt{Z_0}}, b(x) = \frac{V^-(x)}{\sqrt{Z_0}}$~~

$v(x) = \sqrt{Z_0}\, V(x) = a(x) + b(x)$

$i(x) = \sqrt{Z_0}\, I(x) = a(x) - b(x)$

$a(x) = \frac{V(x) + Z_0 I_x}{2\sqrt{Z_0}}$

$b(x) = \frac{V(x) - Z_0 I(x)}{2\sqrt{Z_0}}$

$V_1 = \sqrt{Z_0}(a_1 + b_1)$ $V_2 = \sqrt{Z_0}(a_2 + b_2)$

$I_1 = \frac{1}{\sqrt{Z_0}}(a_1 - b_1)$.

$I_2 = \frac{1}{\sqrt{Z_0}}(a_2 - b_2)$

$P_r = P_{AVS} - P_{in}$

$P_{in} = \frac{1}{2}(V_1 I_1^* + V_1^* I_1)$

$V_1 = \frac{V_s}{Z_{in} + Z_0} \times Z_{in}$

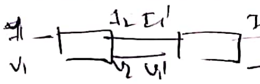
$I_1 = \frac{V_s}{Z_{in} + Z_0}$

$P_{in} = \frac{1}{2}\left[\frac{V_s}{Z_{in} + Z_0} \times Z_{in}\right] \frac{V_s^*}{(Z_{in} + Z_0)^*} + \frac{V_s^* Z_{in}^*}{(Z_{in} + Z_0)^*} \frac{V_s}{(Z_{in} + Z_0)}$

$P_{avs} = \frac{V_s^2}{4 Z_0}$

$P_r = P_{avs} \left|\frac{Z_{in} - Z_0}{Z_{in} + Z_0}\right|^2 = P_{avs} |\Gamma|^2$

ABCD parameters



$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$

$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_2 \\ -I_2 \end{pmatrix}$

$A = \frac{V_1}{V_2} = 1$? open cs short cut

$h_{11} = \frac{V_1}{I_1}$ i/p imped h_{ie}

$h_{21} = \frac{I_2}{I_1}$ forward curr gain h_{fe}

$h_{12} = \frac{V_1}{V_2}$ rev volt gain h_{re}

$h_{22} = \frac{I_2}{V_2}$ o/p adm h_{oe}

condn for lossless

Power equality: power enters = power leaves

$|b_1|^2 + |b_2|^2 = |a_1|^2 + |a_2|^2$

$[b] = [S][a]$

$S_{11} = \frac{A + \frac{B}{Z_0} - C Z_0 - D}{A + \frac{B}{Z_0} + C Z_0 + D}$

$S_{12} = \frac{2(AD - BC)}{\prime\prime}$

$S_{21} = \frac{2}{\prime\prime}$ $S_{22} = \frac{-A + \frac{B}{Z_0} - C Z_0 + D}{\prime\prime}$

$|a_1|^2 = \frac{|V_s|^2}{4 Z_0} = P_{avs}$

S matrix: 1-port

$V^- = V - I Z_0 = V - j\omega C V Z_0$

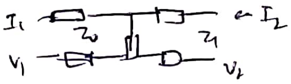
$= V(1 - j\omega C Z_0)$

$V^+ = V + I Z_0 = V + j\omega C V Z_0$

$= V(1 + j\omega C Z_0)$

$S_{11} = \frac{V^-}{V^+} = \frac{X_C - Z_0}{X_C + Z_0}$

2-port shunt element



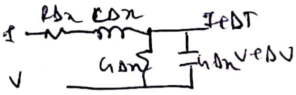
$S_{11} = \frac{Z_0 \| Z_L - Z_0}{Z_0 \| Z_L + Z_0}$

$S_{21} = \frac{b_2}{a_1}\Big|_{a_2 = 0}$ $S = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix}$

$S_{11} = \frac{V_1^-}{V_1^+}\Big|_{V_2^+ = 0}$

$S_{21} = \frac{V_2^-}{V_1^+}\Big|_{V_2^+ = 0}$

Tx lines



$\Delta I = -(G\Delta x + j\omega C \Delta x) V$

$\lim \frac{\Delta I}{\Delta x} = -(G + j\omega C) V$

$\frac{d^2 I}{dx^2} = -(G + j\omega C) \frac{dV}{dx}$

$\Delta V = -(R\Delta x + j\omega L \Delta x) I$

$\lim \frac{\Delta V}{\Delta x} = -(R + j\omega L) I$

$\frac{dV}{dx} = -(R + j\omega L) I$

$\frac{\partial^2 V}{\partial x^2} = \underbrace{(R + j\omega L)(G + j\omega C)}_{\gamma^2} \frac{dV}{dx}$

$\frac{d^2 V}{dx^2} = \gamma^2 \frac{dV}{dx}$

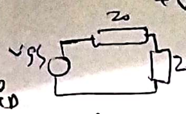
$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$

$V(x, t) = V^+ e^{-\gamma x} + V^- e^{\gamma x}$ Gives forward wave

γ = propagation const

$= \alpha + j\beta$.

$V(x, t) = V^+ e^{-(\alpha + j\beta)x} e^{j\omega t} + V^- e^{(\alpha + j\beta)x} e^{j\omega t}$



$a = \frac{V^+}{\sqrt{Z_0}}$ $b_1 = 0$ $V^+ = V_{gs}$

Lossless:

loss = 0

no charge leakage 0

$R = 0$

$R = 0, G = 0$

$\gamma = j\omega\sqrt{LC} = \alpha + j\beta$

$\alpha = 0, \beta = \omega\sqrt{LC}$

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

$\beta = \frac{2\pi}{\lambda}, v_p = \frac{1}{\sqrt{LC}}$

low loss

$R \ll \omega L$ $G \ll \omega C$

$\gamma = j\omega\sqrt{LC} + \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}}$

$\beta = \omega\sqrt{LC}$

$\alpha = \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}}$

$Z_0 = \sqrt{\frac{L}{C}}\left\{1 - \frac{jR}{2\omega L} + \frac{jG}{2\omega C}\right\}$

Distortionless

$LG = RC$

$Z_0 = \sqrt{\frac{L}{C}}, \gamma = \sqrt{RG} + j\omega\sqrt{LC}$

characteristic imp

$\frac{dV}{dx} = -(R + j\omega L) I$

~~VSWR = 1+~~