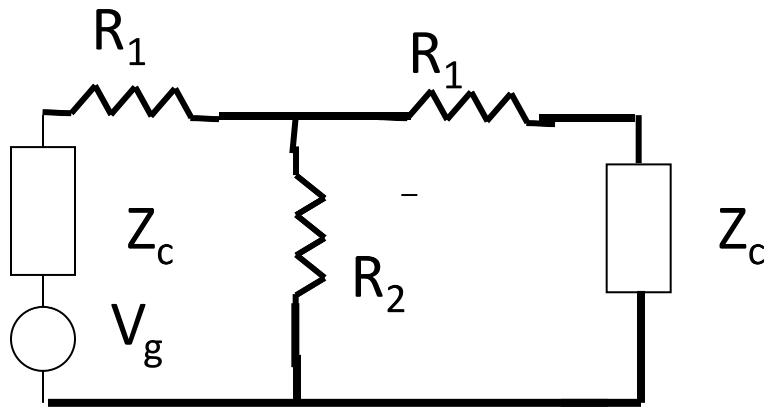
UNIT-2

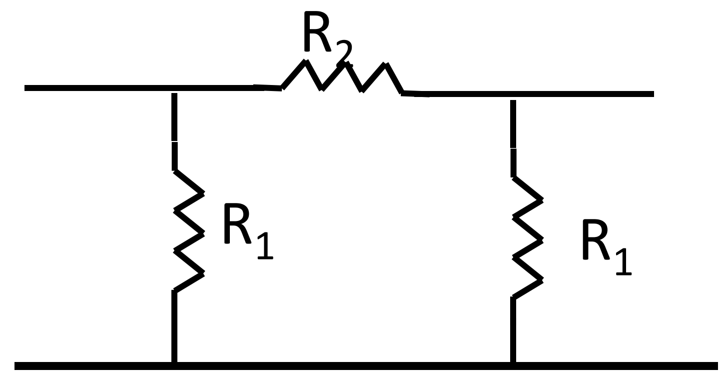
Microwave Engineering

Passive Microwave Devices

Attenuators



T section



π section

$$R_{in} = R_1 + \frac{R_2(R_1 + Z_c)}{R_1 + R_2 + Z_c}$$

$$\text{For } R_{in} = Z_c \Rightarrow R_1(R_1 + 2R_2) = Z_c^2$$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2 + Z_c} \right) V_g$$

The power delivered to the load is :

$$P_L = \frac{1}{2}\left|\frac{V_{TH}}{2Z_c}\right|^2 Z_c = \left(\frac{R_2}{R_1 + R_2 + Z_c}\right)^2 \frac{\left|V_g\right|^2}{8Z_c} = K^2 \frac{\left|V_g\right|^2}{8Z_c}$$

$$K^2 = \left(\frac{R_2}{R_1 + R_2 + Z_c}\right)^2 \quad \text{Power attenuation,} \quad \mathrm{R_{in}} = Z_c \Rightarrow$$

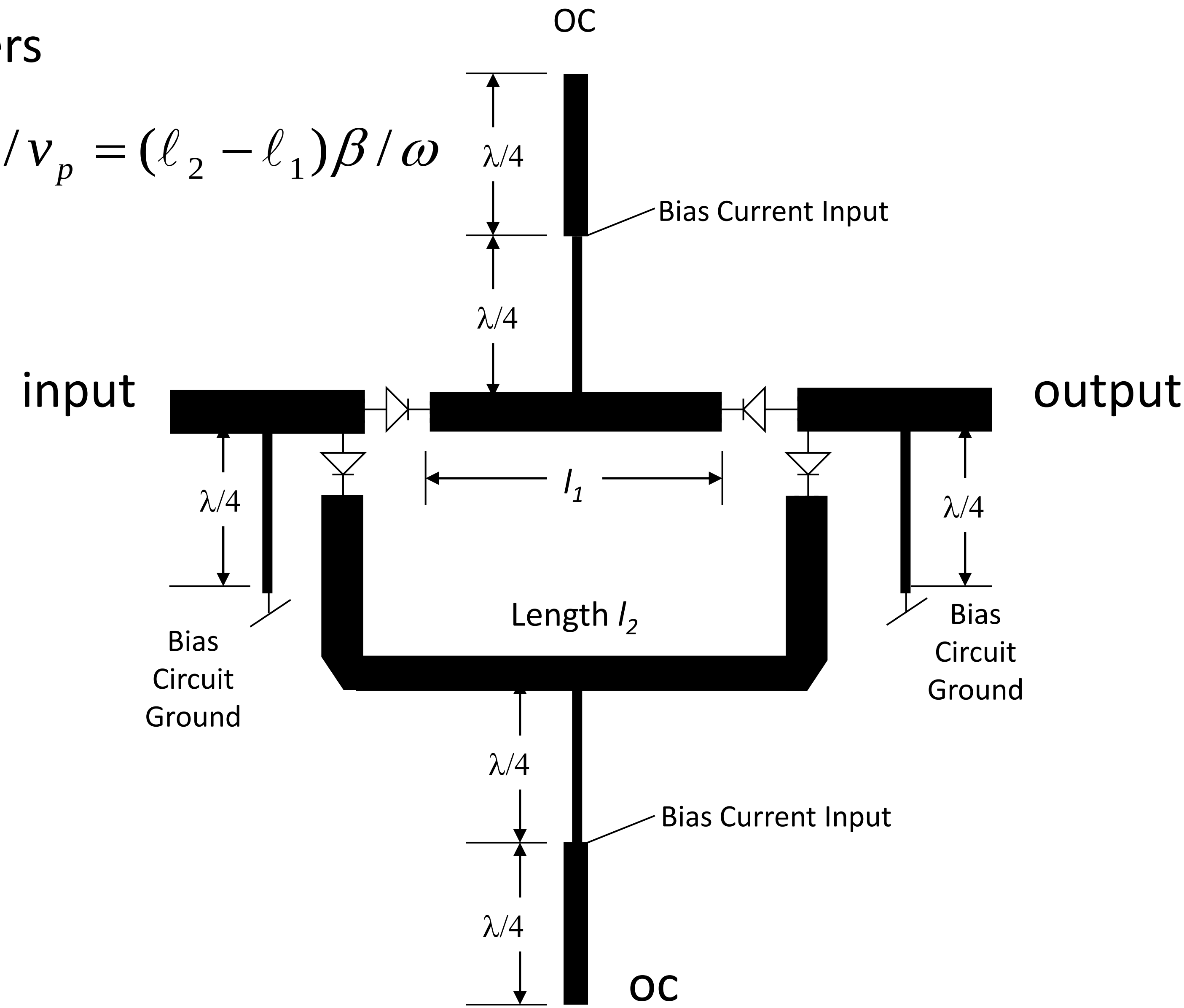
$$\mathrm{R_1} = \frac{1-K}{1+K} Z_c \qquad , \qquad \mathrm{R_2} = \frac{2K}{1-K^2} Z_c$$

For 3-dB attenuator $\mathrm{R_1} = 8.58\Omega$, and $\mathrm{R_2} = 141.4\Omega$.

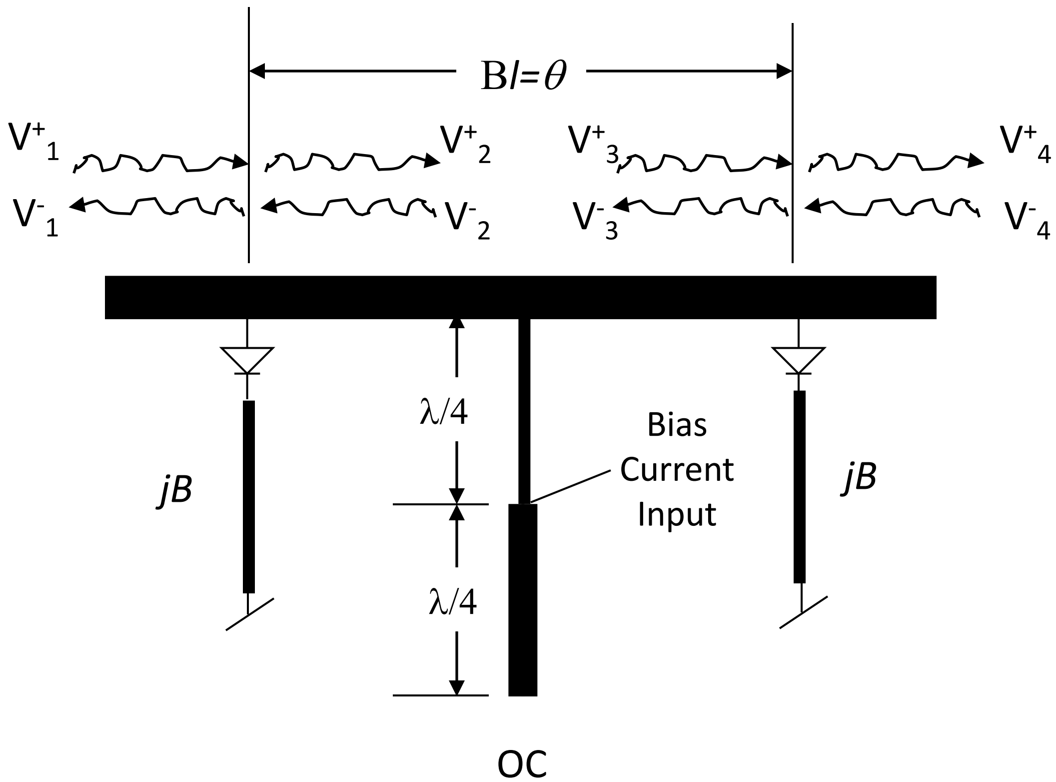
PIN diode can be used in parallel with $\mathrm{R_2}$ in the π-section configuration to switch it in and out of the circuit

Phase shifters

$$\Delta\tau = (\ell_2 - \ell_1)/v_p = (\ell_2 - \ell_1)\beta/\omega$$



Incremental-line-type phase shifter



A phase shifter using switched reactive elements

Transmission matrix of a normalized shunt suceptance *jB:*

$$[A_1] = \begin{bmatrix} 1 + j\frac{\bar{B}}{2} & j\frac{\bar{B}}{2} \\ -j\frac{\bar{B}}{2} & 1 - j\frac{\bar{B}}{2} \end{bmatrix}$$

Transmission matrix of a section of transmission line of Electrical length θ*:*

$$[A_2] = \begin{bmatrix} e^{j\theta} & 0 \\ 0 & e^{-j\theta} \end{bmatrix}$$

Relationship among wave amplitudes:

$$\begin{bmatrix} V_1^+ \\ V_1^- \end{bmatrix} = [A_1]\begin{bmatrix} V_2^+ \\ V_2^- \end{bmatrix} = [A_1][A_2]\begin{bmatrix} V_3^+ \\ V_3^- \end{bmatrix} = [A_1][A_2][A_3]\begin{bmatrix} V_4^+ \\ V_4^- \end{bmatrix}$$

$$= \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}\begin{bmatrix} V_4^+ \\ V_4^- \end{bmatrix}$$

Choose $V^-_4 = 0$, then $V^+_4 = V^+_1 / A_{11}$ Thus $T_{14} = 1/A_{11}$

$$T_{14} = \left[\left(1 + j\frac{\bar{B}}{2}\right)^2 e^{j\theta} + \frac{\bar{B}^2}{4} e^{-j\theta}\right]^{-1}$$

If $tan\,\theta = 2/B$ then : $\quad T_{14} = -e^{j\theta} = e^{-j(\pi-\theta)}, \quad |T_{14}| = 1$

$$\Delta\Phi = (\pi - \theta) - \theta = \pi - 2\theta$$

$$\text{For } \overline{\text{B}} = 2, \theta = \pi/4, \quad \Delta\Phi = \pi/2$$

$$\text{For } \overline{\text{B}} = 1\, \theta = 1.107, \quad \Delta\Phi = 53.14^0$$

Choose the two stubs such that $j\overline{B}_2 = -j\overline{B}_1$

$$T_{14} = \left[\left(1 + j\frac{\overline{B}}{2}\right)^2 e^{j\pi/2} + \frac{\overline{B}^2}{4} e^{-j\pi/2} \right]^{-1} = -j\left[1 + j\overline{B} - \frac{\overline{B}^2}{2}\right]^{-1}$$

$$\approx -j(1 + j\overline{B})^{-1}$$

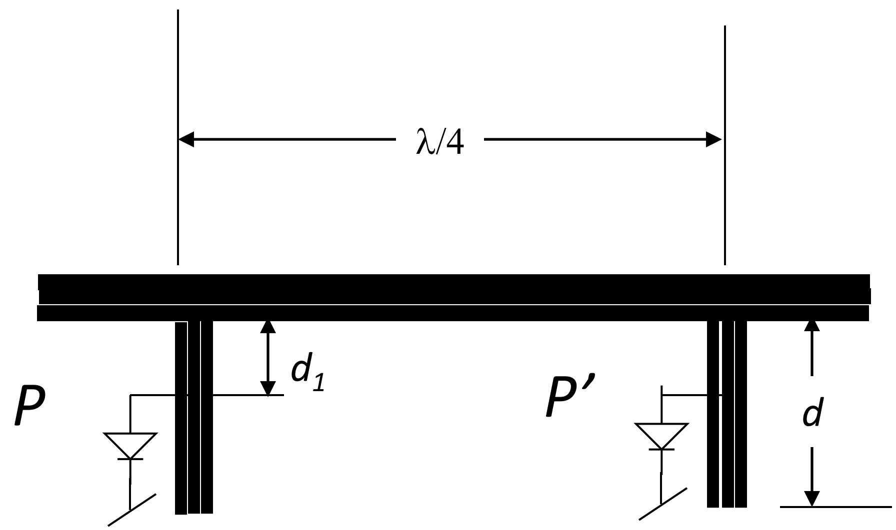
When $\overline{B} << 1, \quad |T_{14}|^2 = (1 + \overline{B}^2)^{-1} \approx 1$

Phase of $T_{14} = -\pi/2 - \tan^{-1}\overline{B} \approx -\pi/2 - \overline{B}$

The change in phase when $\overline{B} = \overline{B}_1$ and $\overline{B} = -\overline{B}_1$ *is* $2\overline{B}_1$

A value of $\overline{B}_1$ as large as $0.2 \Rightarrow \Delta\Phi = .4 = 22.92^0 \Rightarrow$ large mismatch.

This phase shifter is limited o small phase shifts between states in order to keep the input VSWR small



A phase shifter using open circuited stubs spaced $\lambda/4$ Apart. *P* and *P'* are switched into the circuit when the Diodes are off and on, respectively.

$b_1 = 0$ port 1 is matched , $b_2 = 0$ port 2 is decoupled

$\Gamma_e = \Gamma_o = 0 \;\; \Rightarrow \bar{A} + \bar{B} = \bar{C} + \bar{D}, \;\; \bar{\mathrm{A}} = \bar{\mathrm{D}}$ for both even and odd modes,

then $\bar{B} = \bar{C}$ or : $\bar{Z}_{02} = \dfrac{\bar{Z}_{01}}{\sqrt{1 - \bar{Z}_{01}{}^2}}$

$$T = \frac{1}{\bar{A} + \bar{B}} \quad , \quad T_e = -\sqrt{1 - \bar{Z}_{01}{}^2} - j\bar{Z}_{01} \text{ and } \quad T_0 = \sqrt{1 - \bar{Z}_{01}{}^2} - j\bar{Z}_{01}$$

$$b_4 = -j\bar{Z}_{01} a_1 \quad \text{and} \quad b_3 = -\sqrt{1 - \bar{Z}_{01}{}^2}\, a_1$$

$$\text{Coupling} = 10 \log\left(\frac{1}{1 - \bar{Z}_{01}{}^2}\right) \quad \text{, since } P_3 = b_3^2 \;\; \text{and } P_1 = a_1^2$$