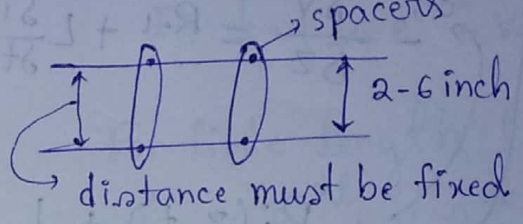
Microwave Integrated Circuits

(Sheuli)
(OE-EC804B)

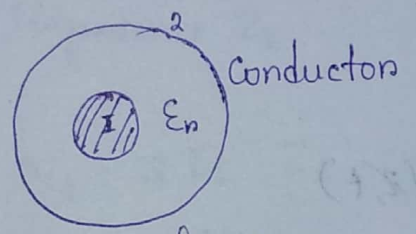
(AKM) 22/3/22

Microwave transmission lines

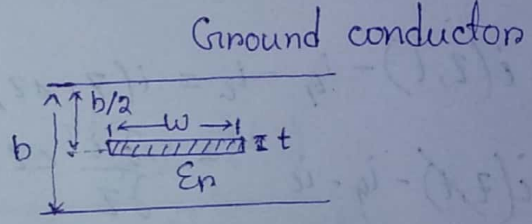
1) Two-wire parallel Transmission-line
2) co-axial
3) strip line
4) waveguide



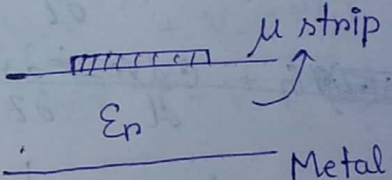
two-wire parallel Tl

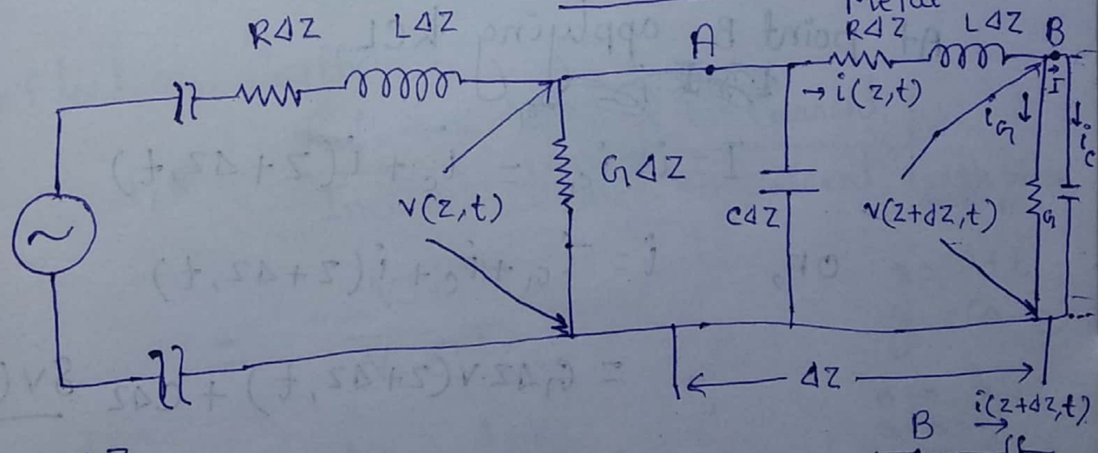


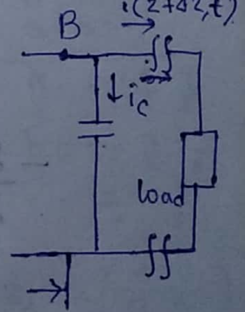
Co-axial Tl



strip line







$R \cdot \Delta z\, i(z,t) + i(z,t) \cdot Ls \cdot \Delta z + i(z,t)\, G\, \Delta z + \dfrac{i(z,t)}{Cs \cdot \Delta z}$

After applying KVL,

$v(z+\Delta z,t) = v(z,t) + \dfrac{\delta(z,t)}{\delta(z)} \Delta z$

$$v(\cancel{z},t) = Ri(z,t)\,\Delta z + L\,\frac{\delta i(z,t)}{\delta(t)}\,\Delta z + \cancel{v(z,t)} + \frac{\delta v(z,t)}{\delta z}\,\Delta z$$

$$\text{or,}\quad -\frac{\delta v}{\delta z} = R\cdot i + L\frac{\delta i}{\delta t} \longrightarrow (1)$$

$$\text{or,}\quad Ri(z,t) + L\,\frac{\delta i(z,t)}{\delta(t)} + \frac{\delta(v,t)}{\delta z} = 0$$

$$i(z,t) - i_G - i_c = i(z+\Delta z, t)$$

$$\cancel{i(z,t)} - i_G - i_c = \frac{\partial i}{\partial z}\cdot\Delta z + \cancel{i(z,t)}$$

$$\text{or}\quad i_G + i_c = -\frac{\partial i}{\partial z}\,\Delta z$$

$$VG + C\frac{\delta v}{\delta t} = -\frac{\delta i}{\delta z}$$

At point B, applying KCL

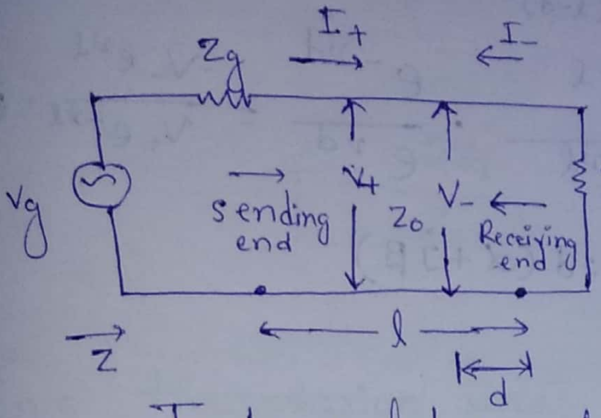
$$I = i - i_G = i_c + i(z+\Delta z, t)$$

$$\text{or,}\quad i = i_G + i_c + i(z+\Delta z, t)$$

$$= G\Delta z\cdot v(z+\Delta z, t) + C\Delta z\,\frac{\delta v(z+\Delta z, t)}{\delta t} + i(z+\Delta z, t)$$

$$-\frac{\delta i}{\delta z} = GV + C\frac{\delta v}{\delta t} \longrightarrow (2)$$

Transmission line - Reflection Coefficient 31/3/22



Tx terminated in a load impedence Z_l

$$V = V_+ e^{-\gamma z} + V_- e^{\gamma z}$$

$$I = \frac{1}{Z_0}\left(V_+ e^{-\gamma z} - V_- e^{\gamma z}\right)$$

For finite length l

$$V_l = V_+ e^{-\gamma l} + V_- e^{\gamma l}$$

$$I_l = \frac{1}{Z_0}\left(V_+ e^{-\gamma l} - V_- e^{\gamma l}\right)$$

$$V_l = I_l \cdot Z_l$$

$$Z_l = \frac{V_l}{I_l} = \frac{\left(V_+ e^{-\gamma l} + V_- e^{\gamma l}\right)}{\frac{1}{Z_0}\left(V_+ e^{-\gamma l} - V_- e^{\gamma l}\right)}$$

$$= Z_0 \cdot \frac{\left(V_+ e^{-\gamma l} + V_- e^{\gamma l}\right)}{\left(V_+ e^{-\gamma l} - V_- e^{\gamma l}\right)}$$

Reflection Coefficient,

$$\Gamma_l = \frac{\text{Reflected Voltage or Current}}{\text{Incident voltage or current}}$$

with phase angle θ

$$= \frac{V_- e^{\gamma l}}{V_+ e^{-\gamma l}}$$

$$= \frac{\frac{V_l}{2} - \frac{I_l Z_0}{2}}{\frac{V_l}{2} + \frac{I_l Z_0}{2}}$$

$$= \frac{Z_l - Z_0}{Z_l + Z_0} \cdot e^{j\theta}$$

$x = a+b$

$y = c(a-b)$

$a+b = x$

$a-b = \frac{y}{c}$

$a = \frac{x}{2} + \frac{y}{2c}$

$b = x - \frac{x}{2} - \frac{y}{2c}$

$= \frac{x}{2} - \frac{y}{2c}$

$Z_l = Z\left(\frac{a+b}{a-b}\right)$

$\frac{Z_l}{Z} = \frac{a+b}{a-b}$

$\frac{2a}{a-b} = \frac{Z_l + Z}{Z}$

$\frac{2b}{a-b} = \frac{Z_l - Z}{Z}$

$a : b$

$Z_l + Z \quad Z_l - Z$

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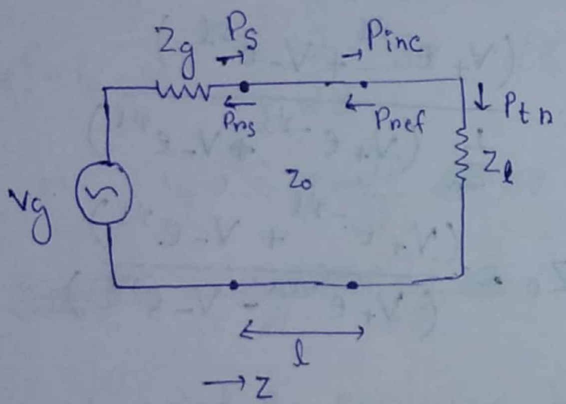
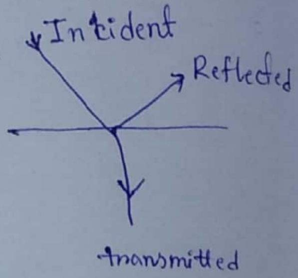
$$\Gamma_{(l-d)} = \frac{V_- e^{\gamma(l-d)}}{V_+ e^{-\gamma(l-d)}}$$

$$= \frac{V_- e^{\gamma l}}{V_+ e^{-\gamma l}} \cdot \frac{e^{-\gamma d}}{e^{\gamma d}} = \frac{V_- e^{\gamma l}}{V_+ e^{-\gamma l}} \cdot e^{-2\gamma d}$$

$$= \Gamma_l \cdot e^{-2d(\alpha + j\beta)}$$

- Transmission line – Transmission coefficient





Transmission Coefficient,

$$= \frac{\text{transmitted voltage or current}}{\text{Incident voltage or current}}$$

$$T = \frac{V_{tn}}{V_{inc}} = \frac{I_{tn}}{I_{inc}}$$

$$V = V_+ e^{-\gamma z} + V_- e^{\gamma z}$$

$$I = \frac{1}{Z_0}\left(V_+ e^{-\gamma z} - V_- e^{\gamma z}\right)$$

$$V_{tn} e^{-\gamma l} = V_+ e^{-\gamma l} + V_- e^{\gamma l}$$

$$I_{tn} e^{\gamma l} = \frac{1}{Z_0}\left(V_+ e^{-\gamma l} - V_- e^{\gamma l}\right)$$

$$\frac{V_{tr}}{Z_l} e^{-\gamma l} = \frac{1}{Z_0}\left(V_+ e^{-\gamma l} - V_- e^{\gamma l}\right) \qquad I_{tr} = \frac{V_{tr}}{Z_l}$$

$$T = \frac{2Z_l}{Z_0 + Z_l}$$

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- In a transmission line, $Z_0 = 75 + j\,0.01\ \Omega$ & $Z_l = 70 + j50\ \Omega$

i) Reflection coefficient

(ii) Transmission "

(iii) Verify relation b/w Γ & T

$$T^2 = \frac{Z_l}{Z_0}(1 - \Gamma^2).$$

$$\Gamma = \frac{Z_l - Z_0}{Z_l + Z_0} \qquad T = \frac{2Z_l}{Z_l + Z_0}$$

$$= \frac{-5 + j(49.99)}{145 + j(50.01)}$$

- Standing Wave :- $(V_s) = V_0 e^{-j\phi}$)

$a - jb = \sqrt{a^2 + b^2}$

$\phi = \tan^{-1}\left(\frac{b}{a}\right)$

$= \arctan(b/a)$

$V = V_+ e^{-\gamma z} + V_- e^{\gamma z}$ (voltage expression of Tx)

$\gamma = \alpha + j\beta$

$$V = V_+ e^{-\alpha z} \cdot e^{-j\beta z} + V_- e^{\alpha z} \cdot e^{j\beta z}$$

$$= A\left[\cos(\beta z) - j\sin(\beta z)\right] + B\left[\cos(\beta z) + j\sin(\beta z)\right]$$

$$= (A + B)\cos(\beta z) - j(A - B)\sin(\beta z)$$

$$V_0 = \sqrt{\underbrace{(A+B)^2}_{m}\cos^2(\beta z) + \underbrace{(A-B)^2}_{n}\sin^2(\beta z)}$$

$$\phi = \arctan\left(\frac{A-B}{A+B}\tan(\beta z)\right)$$

$$\frac{dV_0}{d(\beta z)} = 0$$

or, $$\frac{dV_0}{d(\beta z)} = \frac{1}{2}\left(-2m\cos\beta z\sin\beta z + 2n\sin\beta z\cos\beta z\right)\left[-m\cos^2(\beta z) + n\sin^2(\beta z)\right]^{-1/2} = 0$$

or, $$-2m\sin(\beta z)\cos(\beta z) + 2n\sin(\beta z)\cos(\beta z) = 0$$

or, $$-m\sin 2\theta + n\sin 2\theta = 0$$

or, $$2\sin\theta\cos\theta = 0$$

$\sin\theta = 0$	$\cos\theta = 0$
$\theta = 0, \pm\pi, \pm 2\pi, \pm 3\pi, \ldots$	$\theta = \frac{n\pi}{2}$, $n = 1, \pm 3, \pm 5, \ldots$
$\theta = n\pi$, $n = 0, 1, 2, 3 \ldots$	

$$V_{max} = V_+ e^{-\alpha z} + V_- e^{\alpha z}$$

$$= V_+ e^{-\alpha z}(1 + |\Gamma|)$$

$$V_{min} = V_+ e^{-\alpha z} - V_- e^{\alpha z}$$

$$= V_+ e^{-\alpha z}(1 - |\Gamma|)$$

Voltage standing wave ratio $= \frac{|V_{max}|}{|V_{min}|}$

$$V_{SWR} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

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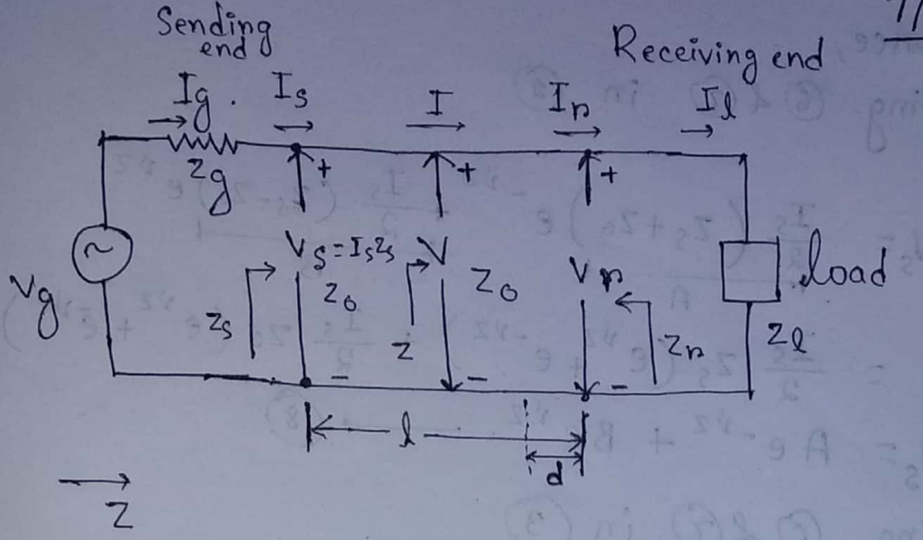

Line Impedence

V_+ = magnitude of incident vol

V_- = magnitude of

$$Z = \frac{V(z)}{I(z)} \longrightarrow (1)$$

$$V = V_+ e^{-\gamma z} + V_- e^{\gamma z} \longrightarrow (2)$$

$$I = \frac{1}{Z_0}\left(V_+ e^{-\gamma z} - V_- e^{\gamma z}\right) \longrightarrow (3)$$

$$= y_0 \left(V_+ e^{-\gamma z} - V_- e^{\gamma z}\right)$$

y_0 = admittance

$$y_0 = \frac{1}{Z_0}$$

$$Z = \frac{\left(V_+ e^{-\gamma z} + V_- e^{\gamma z}\right)}{y_0\left(V_+ e^{-\gamma z} - V_- e^{\gamma z}\right)}$$

At source, $z = 0$

$$V_s = V_+ + V_- = I_s Z_s \longrightarrow (4)$$

$$I_s = y_0 (V_+ - V_-) \longrightarrow (5)$$

$$V_+ + V_- = V_s$$

$$V_+ - V_- = \frac{I_s}{y_0}$$

$$V_+ = \frac{1}{2}\left(V_s + \frac{I_s}{y_0}\right)$$

$$V_- = \frac{1}{2}\left(V_s - \frac{I_s}{y_0}\right)$$

$$V_+ = \frac{1}{2} I_s \left(Z_s + \frac{1}{y_0}\right)$$

$$V_- = \frac{1}{2} I_s \left(Z_s - \frac{1}{y_0}\right)$$

$$Z_0 = \frac{1}{y_0}$$

$$V_+ = \frac{1}{2} I_s (Z_s + Z_0) \longrightarrow (6)$$

$$V_- = \frac{1}{2} I_s (Z_s - Z_0) \longrightarrow (7)$$

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at source,

Putting ⑥ & ⑦ in ②

$$V_s = \underbrace{\frac{I_s}{2}(Z_s + Z_0)}_{A} e^{-\nu z} + \underbrace{\frac{I_s}{2}(Z_s - Z_0)}_{B} e^{\nu z}$$

$$V = \frac{I_s}{2} Z_s (e^{\nu z} + e^{-\nu z}) + \frac{I_s}{2} Z_0 (e^{\nu z} + e^{-\nu z})$$

$$V_s = A e^{-\nu z} + B e^{\nu z} \longrightarrow ⑧$$

Putting ⑥ & ⑦ in ③

$$I_s = \frac{1}{Z_0}\left[\frac{I_s}{2}(Z_s + Z_0)e^{-\nu z} - \frac{I_s}{2}(Z_s - Z_0)e^{\nu z}\right]$$

$$\cancel{= \frac{1}{Z_0}\left[\frac{I_s}{2} Z_s (e^{-\nu z} - e^{\nu z}\right.}$$

$$I_s = \frac{1}{Z_0}\left[A e^{-\nu z} - B e^{\nu z}\right] \longrightarrow ⑨$$

line impedence,

at source

$$Z_s = \frac{V_s}{I_s} = Z_0 \cdot \frac{A e^{-\nu z} + B e^{\nu z}}{A e^{-\nu z} - B e^{\nu z}}$$

For total length (l),

$$Z = Z_0 \frac{(A e^{-\nu l} + B e^{\nu l})}{(A e^{-\nu l} - B e^{\nu l})}$$ ← (line impedence at receiving end)

line impedence at any point,

$$Z = Z_0 \frac{(A e^{-\nu(l-d)} + B e^{\nu(l-d)})}{(A e^{-\nu(l-d)} - B e^{\nu(l-d)})}$$

$$= Z_0 \left(\frac{A e^{-\nu l} \cdot e^{\nu d} + B e^{\nu l} \cdot e^{-\nu d}}{A e^{-\nu l} \cdot e^{\nu d} - B \cdot e^{\nu l} \cdot e^{-\nu d}}\right)$$