Microwave Integrated Circuits (OE-EC 804 B)

Frequency range 300 MHz to 300 GHz

$E = h\nu = h\frac{c}{\lambda}$

Frequency $= c/\lambda$

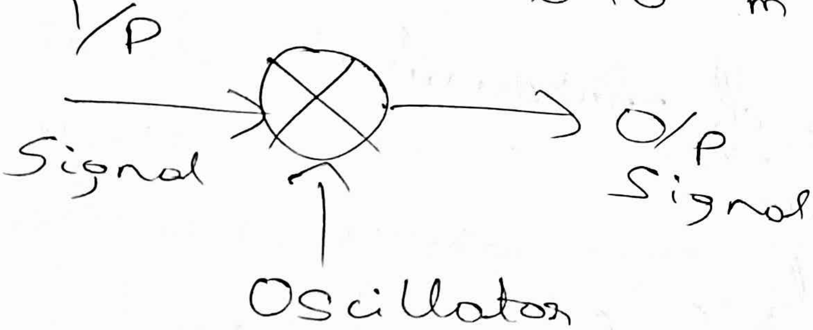
$\times 100$

$3 \times 10^{6} = \frac{3 \times 10^{8}}{\lambda}$

$\lambda = \cancel{100}\ 1\,m$

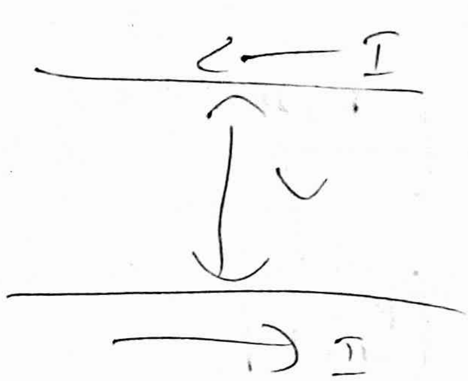
$\cancel{3} \times \cancel{10^{9}} \times 100 = \frac{\cancel{3 \times 10^{8}}}{\lambda}$

$\Rightarrow \lambda = 10^{-3}\,m$



$R = \rho \frac{l}{A}$

Ideal



$$V = IR \rightarrow R = \frac{V}{I}$$

$\frac{V(x)}{I(x)}$

$$Y = X = R + j\omega L + \frac{1}{j\omega C}$$

MESFET

· because of metal semiconductor contact, on applying small voltage, we get ~~high~~ current.

MIC

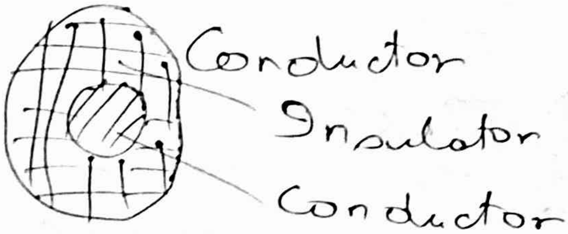
Microwave Transmission Lines

1) Two-Wire Parallel T.L.
2) Co-axial ~~Cable~~
3) Strip line
4) Waveguide

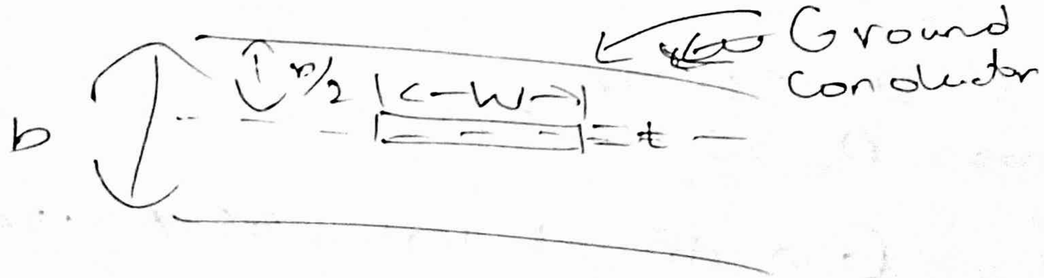
1) Two-wire Tx line

Disadvantage
1) Loss of energy is high.

2) Co-axial Cable

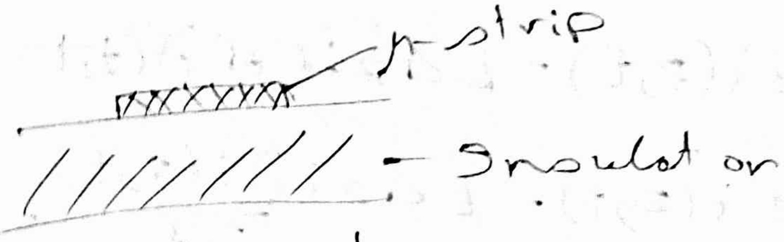


3) Strip-line

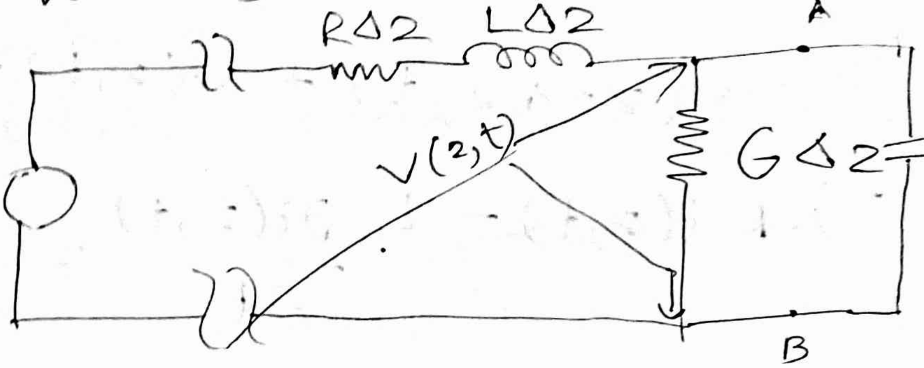


Ground should be minimum 5 times greater than b.

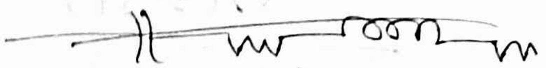
Disadvantage
i) It is inside dielectrics, so its position can't be changed ~~in orientation~~ to when required

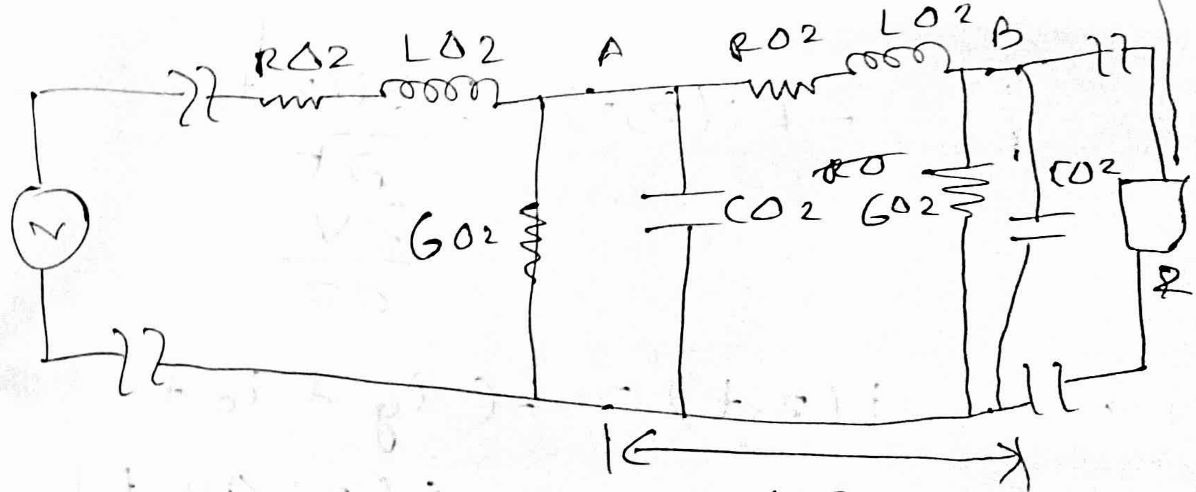


A) Waveguide



→ Z





(z,t)

$$-i(z,t)R\Delta z - L\Delta z\frac{\partial i(z,t)}{\partial t} - v(z+\Delta z,t) + v(z,t) = 0$$

$$\frac{v(z+\Delta z,t) - v(z,t)}{\Delta z} = -i(z,t)R - L\frac{\partial i(z,t)}{\partial t}$$

$-R\Delta z\, i(z,t) - \cancel{L\Delta z\, i(t)\, \partial(z,t}$

$-R\Delta z\, i(z,t) - L\Delta z\, i \dfrac{\partial i(z,t)}{\partial t} -$

$v(z+\Delta z, t) + v(z,t) = 0$

$\Rightarrow -R\, i(z,t) - L \dfrac{\partial i(z,t)}{\partial t} =$

∂v

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

$\Rightarrow -R\, i(z,t) - L \dfrac{\partial i(z,t)}{\partial t} = \dfrac{\partial v}{\partial z}$

$i(z,t) = \cancel{i}(\, i_g + i_c + i(z+\Delta z, t)$

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

$\Rightarrow -v(z+\Delta z, t)\, G\Delta z - \dfrac{\partial v(z+\Delta z, t)}{\partial t} C\Delta z = i(z+\Delta z, t) - i(z,t)$

$\Rightarrow$

$$\Rightarrow -V(z+\Delta z,t)\,G - \frac{\partial V(z+\Delta z,t)}{\partial t}\,C = \frac{\partial i(z,t)}{\partial \cancel{t} z}$$

$$\cancel{V(z)} -$$

$$V(z,t) - \cancel{R(\Delta z)}\, R\Delta z\, \cancel{\frac{\partial i(z,t)}{\partial t}} - \cancel{L\Delta z\, \partial i}$$

$$R\Delta z\, i(z,t) - L\Delta z \frac{\partial i(z,t)}{\partial t} = V(z+\Delta z,t)$$

Characteristic Impedance

$$\frac{dv}{dz} = -ZI \quad \text{---} \quad (1)$$

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

$$I = -\frac{1}{Z}\frac{dv}{dz}$$

$$\cancel{\frac{dI}{dz} = -\frac{1}{Z^2}\frac{d^2 z}{dz^2}}$$

$$\frac{dI}{dz} = +\frac{1}{Z^2}\frac{dv}{dz} - \frac{1}{Z}\frac{d^2 v}{dz^2}$$

$$\cancel{-\frac{1}{Z}\frac{d^2 v}{dz^2}}$$

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

$$-\frac{1}{Z}\left(\cancel{-e^{-\gamma z}} - \gamma V_+ e^{-\gamma z} + \gamma V_- e^{\gamma z}\right)$$

$$\gamma V I_+ e^{-\gamma z} \mp \gamma V I_- e^{-\gamma z}$$

$$= \cancel{\gamma}\, \frac{\gamma}{Z}\left[V_+ e^{-\gamma z} - V_- e^{\gamma z}\right]$$

$\gamma = \sqrt{ZY}$

$$\frac{V}{Z} \quad \frac{\gamma}{Z} = \frac{\sqrt{ZY}}{Z}$$

$$= \sqrt{\frac{Y}{Z}}$$

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

$$I = \sqrt{\frac{G+j\omega C}{R+j\omega L}} \left[V_+ e^{-\gamma z} - V_- e^{\gamma z}\right]$$

$$= \frac{1}{\sqrt{\frac{R+j\omega L}{G+j\omega C}}} \left[V_+ e^{-\gamma z} - V_- e^{\gamma z}\right]$$

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

For lossless line $R = 0, G = 0$.

$$Z_0 = \sqrt{L/C}$$

~~For~~ At μ-wave frequency

$\omega L, \omega C$

$R << \omega L,$

$G << \omega C$

Propogation constant

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

$$= (R+j\omega L)^{1/2} (G+j\omega C)^{1/2}$$

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

A Using binomial $(1+0.000001)^2$ approximation, we get

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

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

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

$1+$

$$=$$

$$\frac{1}{2}\left[R\sqrt{\frac{C}{L}}+G\sqrt{\frac{L}{C}}\right]+j\omega\sqrt{LC}$$

$$=\alpha+j\beta$$

Calculate characteristic ~~impeda~~ impedance at high ~~frequ~~ ~~frequ~~ frequency

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

$$\cancel{=\sqrt{\frac{C}{L}}\sqrt{\frac{R}{j\omega L}+1}}=\cancel{\sqrt{\frac{L}{C}}\sqrt{\frac{\frac{R}{j\omega L}+1}{G}}}$$

$$= \sqrt{\frac{L}{C}} \sqrt{\frac{\frac{R}{j\omega L}+1}{\frac{G}{j\omega C}+1}}$$

$$= \sqrt{L/C}$$

$\left[\because \frac{R}{j\omega L} \approx 0\right.$ & $\frac{G}{\omega C} \approx 0$ since ω is very high$\left.\right]$

Rate of change of phase w.r.to direction

~~$V = v(z,t) =$~~

$$v(z,t) = \cancel{Re}\ Re\left|V e^{j\omega t}\right|$$

$$e^{j\omega t} = \cos(\omega t - \beta z)$$

$$\omega t - \beta z = \text{constant}$$

Phase ~~velocity~~ velocity

$$v_p = \frac{dz}{dt} = \frac{\omega}{\beta}$$

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

$$\frac{\omega}{\beta} =$$

$$v_p = \frac{\omega}{\omega\sqrt{LC}} = \frac{1}{\sqrt{LC}}$$

$$\omega - \beta\frac{dz}{dt} = 0 \rightarrow v_p = \frac{\omega}{\beta}$$