UNIT-2

★ Transmission Line :-

The transfer the energy from one pt to another through either transmission line or wave guide.

The electrical ~~waves~~ lines which transmit the electrical wave one place to another.

The example is telephone cables, electri-cal power signal.

★ Types of transmission line

- Open wire line :- It is not insulated ~~whic~~ with any thing. Eg: telephone line and electrical signal lines.

- Cables :- These are underground lines. These are insulated by platics or papers.

- Co-axial cable :- It has two conductor one is hollow and other is placed coaxially under the 1st material.

- Wave guides :- These are used to transmit the micro wave frequency.

  Range of micro wave frq :- 1 GHz - 300 GHz

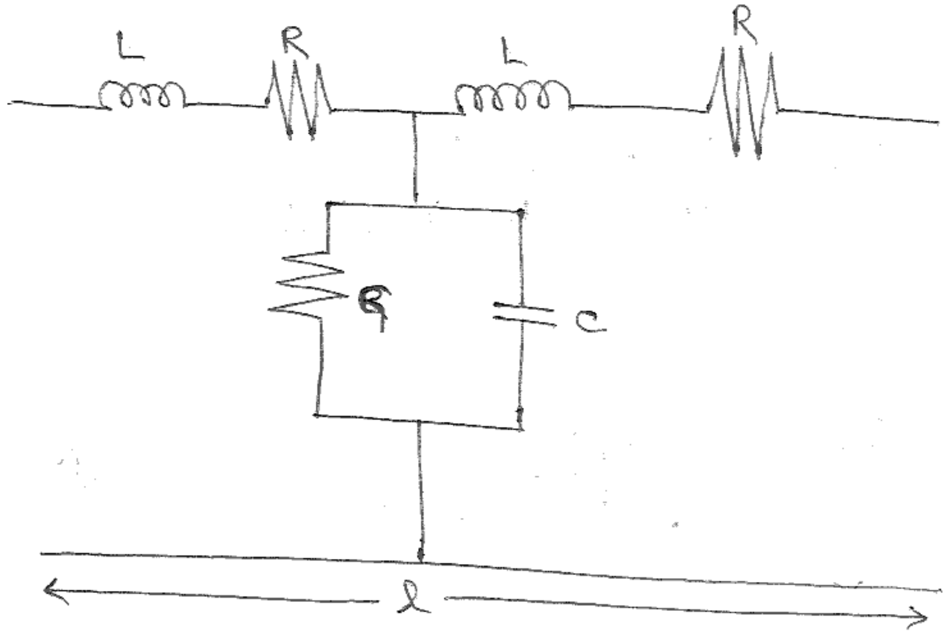
2 marks
Imp * Parameter in transmission line

- Resistance (R)
- Inductance (L)
- Capacitance (C)
- Conductance (G) $= \frac{1}{R}$

Imp *Characteristic Impedance (Z_0)
2 marks

The characteristic impedance of symmetrical n/w is the impedance measured at the i/p terminal of the 1st channel in the chain of infinite n/w in cascade and it is represented by Z_0.

★ Equivalent circuit of Transmission Line



The parameters R, L, C and G are distributed through out the transmission line.

The serial impedance ~~by the~~ of the eq ckt is represented by

$$Z = R + j\omega L$$

The shunt ~~impedance~~ admittance is represented by

$$Y = G + j\omega C$$

When the length is l then,

$$Z_1 = (R + j\omega L)\, l$$

$$Y_1 = (G + j\omega C)\, l$$

We know that

$$Z = \frac{1}{Y}$$

$$Z_2 = \frac{1}{Y_1} = \frac{1}{(G + j\omega C)\, l}$$

$$Z_0 = \sqrt{\frac{Z_1^2}{4} + Z_1 Z_2} \quad \text{—— } ①$$

$\downarrow$

Char. impe of total n/w

$$Z_0 = \sqrt{\frac{(R + j\omega L)^2\, l^2}{4} + \frac{(R + j\omega L)\cancel{l}}{(G + j\omega C)\cancel{l}}}$$

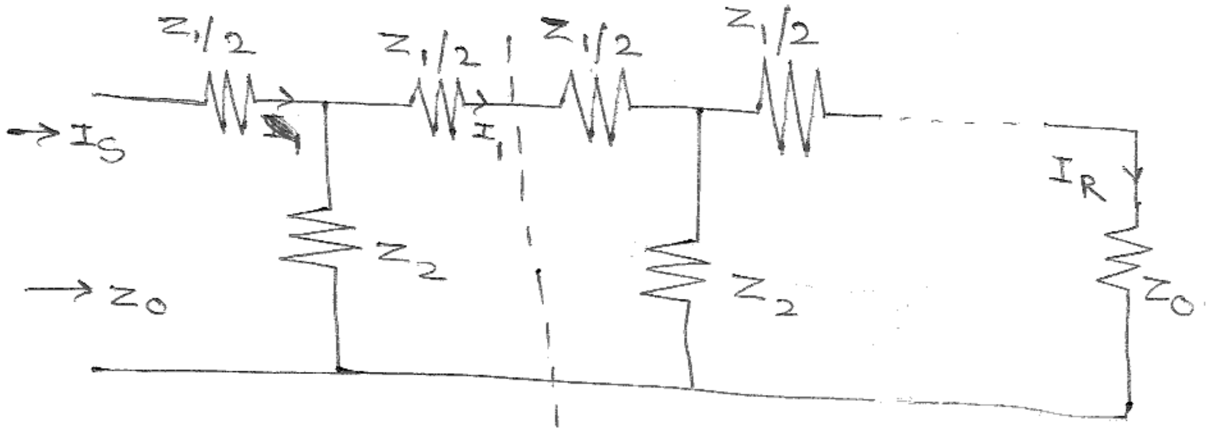
$$= \sqrt{\frac{(R + j\omega L)^2\, l^2}{4} + \frac{R + j\omega L}{G + j\omega C}}$$

Let us assume length is very short

So, $l = 0$

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

* Transmission lines as cascaded T section.



Here,

I_S = sending current

I_R = receiving current

The sending current

$$\boxed{I_S = I_R e^{n\gamma}}$$

where

n = no. of network

γ = ~~proportionality~~ propagation constant

ort

$$\gamma = \alpha + i\beta$$

where

α = attenuation (loss)

β = phase shift

The receiving current at 1st n/w I_1

$$I_1 = I_S \times \frac{Z_2}{Z_{1/2} + Z_0 + Z_2}$$

$$\frac{I_S}{I_1} = \frac{Z_{1/2} + Z_0 + Z_2}{Z_2}$$

WKT

$$\frac{I_S}{I_R} = e^{n\gamma}$$

$$\therefore \frac{I_S}{I_1} = e^{\gamma}$$

$$\therefore e^{\gamma} = 1 + \frac{Z_0}{2} + \frac{Z_{1/2}}{Z_2}$$

For 2nd n/w

$$\frac{I_1}{I_2} = 1 + \frac{Z_0}{2} + \frac{Z_{1/2}}{Z_2}$$

Taking two n/w

$$\frac{I_S}{I_2} = \frac{I_S}{I_1} \times \frac{I_1}{I_2} = e^{2\gamma}$$

$$\therefore \frac{I_S}{I_R} = e^{n\gamma}$$

$$\frac{I_{R-1}}{I_R} = e^{(n-1)\gamma}$$

2marks

$\underline{Q1}$ ★ Propagation constant (γ)

It is defined as the natural logarithm of the ratio of sending end current or voltage to receiving end current or voltage.

$$\gamma = \ln \frac{I_S}{I_R} \quad \text{or,}$$

$$\gamma = \ln = \frac{V_S}{V_R}$$

$$\gamma = \alpha + j\beta$$

It is also known as

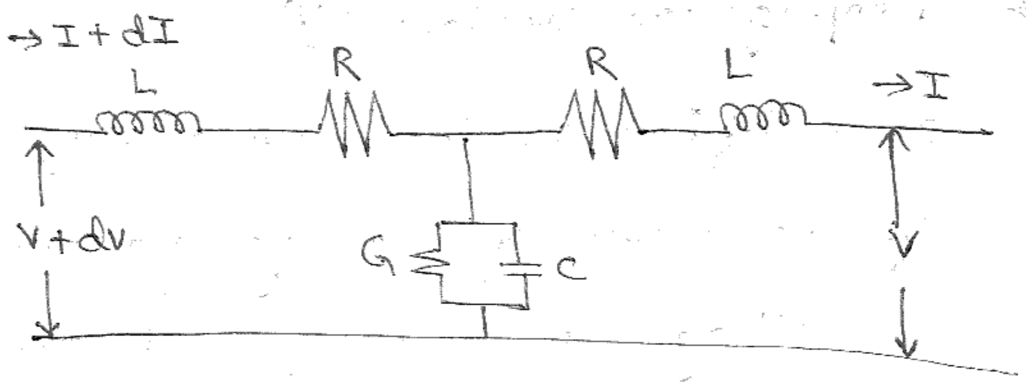
$$\gamma = \sqrt{zy}$$

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

* The general solution Transsion line

or

Transition Line Equation



L, R, C and G are transdution line parameter.

The series impedance is

$$Z = R + j\omega L$$

The shunt admittance of the line

$$Y = G + j\omega C$$

consider the transduction line is having some distance dx.

~~Consider the~~ The impedance will be

$$(R + j\omega L)\, dx$$

The shunt admittance will be

$$(G + j\omega C)\, dx$$

~~V~~, I is the output voltage and current of the trans. line.

The potential difference b/w two ends

$$V + dV - V = I(R + j\omega L)\,dx$$

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

$$\frac{dV}{dx} = IZ \qquad \text{—— } (1)$$

The current diff into i/p and o/p of the line

$$I + dI - I = V(G + j\omega C)\,dx$$

$$\frac{dI}{dx} = VY \qquad \text{—— } (2)$$

diff eq (1) w.r.t x

$$\frac{d^2V}{dx^2} = (R + j\omega L)\frac{dI}{dx}$$

$$\frac{d^2V}{dx^2} = (R + j\omega L)(G + j\omega C)V \qquad \text{—— } (3)$$

lly, diff. (2) w.r.t. x

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

$$\therefore \frac{d^2I}{dx^2} = (G + j\omega C)(R + j\omega L)I \qquad \text{—— } (4)$$

We know that

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

Sub the value of γ in 3 and 4

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

$$\frac{d^2 I}{dx^2} = \gamma^2 I$$

$$(m^2 - \gamma^2)V = 0$$

$$m = \pm \gamma$$

Also,

$$(m^2 - \gamma^2)I = 0$$

$$m = \pm \gamma$$

$$V = Ae^{\gamma x} + Be^{-\gamma x} \quad \text{— } (5)$$

$$I = Ce^{\gamma x} + De^{-\gamma x} \quad \text{— } (6)$$

where, A, B, C, D are arbitrary constant.

Again, diff 5 w.r. to x

$$\frac{dV}{dx} = A\gamma e^{\gamma x} - B\gamma e^{-\gamma x}$$

From 1, $\frac{dV}{dx} = Iz$

So, $Iz = A\gamma e^{\gamma x} - B\gamma e^{-\gamma x}$

$$\gamma = \sqrt{ZY}$$

$$\therefore \; IZ = A\sqrt{ZY}\, e^{\sqrt{ZY}\,x} - B\sqrt{ZY}\, e^{-\sqrt{ZY}\,x}$$

$$I = A\sqrt{\frac{Y}{Z}}\, e^{\sqrt{ZY}\,x} - B\sqrt{\frac{Y}{Z}}\, e^{-\sqrt{ZY}\,x} \quad \text{--- (7)}$$

lly, diff eq (6) w.r. to x

$$\frac{dI}{dx} = C\gamma e^{\gamma x} - D\gamma e^{-\gamma x}$$

$$VY = C\gamma e^{\gamma x} - D\gamma e^{-\gamma x}$$

$$VY = C\sqrt{ZY}\, e^{\sqrt{ZY}\,x} - D\sqrt{ZY}\, e^{-\sqrt{ZY}\,x}$$

$$V = C\sqrt{\frac{Z}{Y}}\, e^{\sqrt{ZY}\,x} - D\sqrt{\frac{Z}{Y}}\, e^{-\sqrt{ZY}\,x} \quad \text{--- (8)}$$

If the transmission line is short line $x = 0$ and replace the value $I = \cancel{E_R}$ I_R

~~V = VR~~ $V = V_R$

These condition are applied to (5) and (6)

$$V_R = A + B \quad \text{--- (9)}$$

$$I_R = C + D \quad \text{--- (10)}$$

Same condition is applied to (7) and (8)

$$I_R = A\sqrt{\frac{Y}{Z}} - B\sqrt{\frac{Y}{Z}} \quad \text{--- (11)}$$

$$V_R = C\sqrt{\frac{Z}{Y}} - D\sqrt{\frac{Z}{Y}} \quad \text{— (12)}$$

Take,

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

$$\Rightarrow \frac{1}{x} = \sqrt{\frac{Y}{Z}}$$

So,

$$I_R = \frac{A}{x} - \frac{B}{x} = \frac{1}{x}(A-B)$$

compair the above eq with eq (10)

$$C + D = \frac{1}{x}(A-B) \quad \text{—} \cancel{13}$$

$$Cx + Dx = A - B \quad \text{— (13)}$$

IIly,

$$V_R = Cx - Dx$$

compair the above eq with eq (9)

$$A + B = Cx - Dx \quad \text{— (14)}$$

$$A - B = Cx + Dx \quad \text{— (13)}$$

Adding (13) and (14) we get

$$2A = 2Cx$$

$$A = Cx$$

Subtracting (13) and (14) we get

$$2B = -2Dx$$

$$B = -Dx$$

Sub the value of A and B in eq (9)

$$V_R = A + B = Cx - Dx \quad \text{--- (15)}$$

From eq (10) $I_R = C + D$

mult by x in eq (10)

$$I_R x = Cx + Dx \quad \text{--- (16)}$$

Adding eq (15) and (16)

$$V_R + I_R x = 2Cx$$

$$2C = I_R + \frac{V_R}{x}$$

$$C = \frac{I_R}{2} + \frac{V_R}{2x}$$

$$C = \frac{I_R}{2} + \frac{V_R}{2}\sqrt{\frac{Y}{Z}} \quad \text{--- (17)}$$

Subtracting eq (15) and (16)

$$-2Dx = V_R - I_R x$$

$$2Dx = I_R x - V_R$$

$$D = \frac{I_R}{2} - \frac{V_R}{2x} = \frac{I_R}{2} - \frac{V_R}{2}\sqrt{\frac{Y}{Z}}$$

--- (18)

Sub. the value

$$A = C x$$

$$A = \frac{I_R}{2} x + \frac{V_R}{2} \sqrt{\frac{Y}{Z}} \cdot x$$

$$A = \frac{V_R}{2} + \frac{I_R}{2} \sqrt{\frac{Z}{Y}} \quad — (19)$$

$$B = -D x$$

$$B = -\frac{I_R}{2} + \frac{V_R}{2} \sqrt{\frac{Y}{Z}} \cdot x$$

$$= \frac{V_R}{2} - \frac{I_R x}{2}$$

$$B = \frac{V_R}{2} - \frac{I_R}{2} \sqrt{\frac{Z}{Y}} \quad — (20)$$

Replace $\sqrt{\frac{Z}{Y}}$ by Z_0

The characteristic eq Z_0 will be

From ohm's law

$$V_R = I_R Z_R \quad I_R = \frac{V_R}{Z_R}$$

$$Z_0 = \sqrt{\frac{Z}{Y}}$$

$$A = \frac{V_R}{2} + \frac{V_R}{2Z_R} \cdot Z_0 = \frac{V_R}{2} \left(1 + \frac{Z_0}{Z_R}\right) — (21)$$

$$B = \frac{V_R}{2} - \frac{V_R}{2Z_R} \cdot Z_0 = \frac{V_R}{2} \left(1 - \frac{Z_0}{Z_R}\right) — (22)$$

$$C = \frac{I_R}{2} + \frac{I_R Z_R}{2} \cdot \frac{1}{Z_0}$$

$$C = \frac{I_R}{2}\left(1 + \frac{Z_R}{Z_0}\right) \quad \text{--- (23)}$$

$$D = \frac{I_R}{2} - \frac{I_R Z_R}{2} \frac{1}{Z_0}$$

$$D = \frac{I_R}{2}\left(1 - \frac{Z_R}{Z_0}\right) \quad \text{--- (24)}$$

Subst the value A, B, C and D in eq (5) and eq (6)

$$V = \frac{V_R}{2}\left(1 + \frac{Z_0}{Z_R}\right) e^{\gamma x} + \frac{V_R}{2}\left(1 - \frac{Z_0}{Z_R}\right) e^{-\sqrt{ZY}\,x}$$

— (25)

$$I = \frac{I_R}{2}\left(1 + \frac{Z_R}{Z_0}\right) e^{\sqrt{ZY}\,x} + \frac{I_R}{2}\left(1 - \frac{Z_R}{Z_0}\right) e^{-\sqrt{ZY}\,x}$$

— (26)

From eq (25)

— (21)

$$V = \frac{V_R}{2} e^{\sqrt{ZY}\,x} + \frac{V_R}{2} \frac{Z_0}{Z_R} e^{\sqrt{ZY}\,x} +$$

-(22)

$$\frac{V_R}{2} e^{-\sqrt{ZY}\,x} - \frac{V_R}{2} \frac{Z_0}{Z_R} e^{-\sqrt{ZY}\,x}$$

$$V = V_R\left[\frac{e^{\sqrt{ZY}\,x} + e^{-\sqrt{ZY}\,x}}{2}\right] + \frac{V_R Z_0}{Z_R}\left[\frac{e^{\sqrt{ZY}\,x} - e^{-\sqrt{ZY}\,x}}{2}\right]$$

Put $V_R = I_R Z_R$.

$$V = V_R\left[\frac{e^{\sqrt{ZY}x} + e^{-\sqrt{ZY}x}}{2}\right] + I_R Z_0\left[\frac{e^{\sqrt{ZY}x} - e^{-\sqrt{ZY}x}}{2}\right]$$

$$V = V_R \cosh\sqrt{ZY}\,x + I_R Z_0 \sinh\sqrt{ZY}\,x \qquad \text{— (27)}$$

From (26)

$$I = \frac{I_R}{2} e^{\sqrt{ZY}\,x} + \frac{I_R}{2} e^{\sqrt{ZY}\,x}\,\frac{Z_R}{Z_0}$$

$$+ \frac{I_R}{2} e^{-\sqrt{ZY}\,x} - \frac{I_R}{2} e^{-\sqrt{ZY}\,x}\,\frac{Z_R}{Z_0}$$

$$I = I_R\left[\frac{e^{\sqrt{ZY}\,x} + e^{-\sqrt{ZY}\,x}}{2}\right]$$

$$+ \frac{I_R Z_R}{Z_0}\left[\frac{e^{\sqrt{ZY}\,x} - e^{-\sqrt{ZY}\,x}}{2}\right]$$

$$I = I_R \cosh\sqrt{ZY}\,x + \frac{V_R}{Z_0}\sinh\sqrt{ZY}\,x \qquad \text{— (28)}$$

These two (27) and (28) are general solution of transmission line.

* Physical Signification of General Solution

Sending impedance Z_S is the ratio of sending voltage and sending current.

i.e.

$$Z_S = \frac{V_S}{I_S}$$

$$V_S = V_R \cosh \gamma l + I_R Z_0 \sinh \gamma l$$

where,

$$\gamma = \sqrt{ZY}$$

$$I_S = I_R \cosh \gamma l + \frac{V_R}{Z_0} \sinh \gamma l$$

$$\therefore Z_S = \frac{I_R Z_R \cosh \gamma l + I_R Z_0 \sinh \gamma l}{I_R Z_0 \cosh \gamma l + \frac{I_R}{Z_0} Z_R \sinh \gamma l}$$

where,

$$V_R = I_R Z_R$$

$$Z_S = \frac{Z_R \cosh \gamma l + Z_0 \sinh \gamma l}{\frac{Z_0 \cosh \gamma l + Z_R \sinh \gamma l}{Z_0}}$$

$$Z_S = Z_0 \left[\frac{Z_R \cosh \gamma l + Z_0 \sinh \gamma l}{Z_0 \cosh \gamma l + Z_R \sinh \gamma l} \right]$$

when the line is terminated $Z_R = Z_0$

$$Z_S = Z_0$$

The transmission line is of infinite length $l = \infty$

$$Z_S = Z_0 \frac{\cancel{\cosh \gamma l} \left[Z_R + Z_0 \frac{\sinh \gamma l}{\cosh \gamma l}\right]}{\cancel{\cosh \gamma l} \left[Z_0 + Z_R \frac{\sinh \gamma l}{\cosh \gamma l}\right]}$$

$$Z_S = \frac{Z_0 [Z_R + Z_0 \tanh \gamma l]}{Z_0 + Z_R \tanh \gamma l}$$

$$l = \infty$$

$$Z_S = Z_0 \frac{\cancel{Z_R} + Z_0}{Z_0 + \cancel{Z_R}}$$

$$Z_S = Z_0$$

★ Reflection Co-efficient

It is defined as the ratio of reflected voltage to the incident voltage at the receiving end. Denoted by K.

$$K = \frac{\text{Reflected voltage}}{\text{Incident voltage}} = \frac{V_R}{V_S}$$

The general voltage equation of transmission line

$$V = \frac{V_R}{2}\left[\left(1+\frac{Z_0}{Z_R}\right)e^{\gamma x} + \left(1-\frac{Z_0}{Z_R}\right)e^{-\gamma x}\right]$$

From eq (25) ↑

$$K = \frac{V_R}{2}\left[\left(\frac{Z_R+Z_0}{Z_R}\right)e^{\gamma x} + \frac{Z_R-Z_0}{Z_R}e^{-\gamma x}\right]$$

$$\cancel{K} = V_R\,\frac{Z_R+Z_0}{2Z_R}\left[e^{\gamma x} + \frac{Z_R-Z_0}{Z_R+Z_0}e^{-\gamma x}\right]$$

$$= \frac{V_R}{2}\,\frac{Z_R+Z_0}{Z_R}e^{\gamma x} - \frac{V_R}{2}\,\frac{Z_R-Z_0}{Z_R}e^{-\gamma x}$$

The first term $e^{\gamma x}$ represent the incident wave.

The 2nd term $e^{-\gamma x}$ represent the reflecte wave.

$$K = \frac{\cancel{\frac{V_R}{2}}\,\frac{Z_R-Z_0}{Z_R}}{\cancel{\frac{V_R}{2}}\,\frac{Z_R+Z_0}{Z_R}}$$

$$\boxed{K = \frac{Z_R-Z_0}{Z_R+Z_0}}$$

It is also defined in the terms of ratio of reflected current to incident current but it is -ve.

If the trans. line terminated by char. impedance $Z_R = Z_0$. At that time the reflec. coeff. becomes zero.

★ Wave length And Velocity Propagation

The distance travelled by the wave along the line which the phase angle is changing through 2π radiance is called wave length.

$$\beta\lambda = 2\pi$$

$$\lambda = \frac{2\pi}{\beta}$$

velocity propagation:-

W.K.T

$$\gamma = \sqrt{ZY}$$

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

Squaring both side

of
dent

har.

the

we
angle
is

$$\gamma^2 = (R+j\omega L)(G+j\omega C)$$

$$= RG + Rj\omega C + Gj\omega L - \omega^2 LC$$

$$= (RG - \omega^2 LC) + j\omega(RC + GL)$$

Here, the mini attenuation

$$L = \frac{RC}{G}$$

$$LG = RC$$

$$\gamma^2 = RG - \omega^2 LC + 2j\omega RC$$

$$\gamma^2 = RG - \omega^2 LC + j2\omega\sqrt{RCLG}$$

$$\gamma^2 = (\sqrt{RG} + j\omega\sqrt{LC})^2$$

$$\gamma = \sqrt{RG} + j\omega\sqrt{LC}$$

$$\gamma = \alpha + i\beta$$

$$\alpha = \sqrt{RG}$$

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

The veloc. propagation is given by $v = \lambda f$
mult. & divi. by 2π

$$V = \frac{\lambda}{2\pi} \cdot f\,2\pi$$

$$= \frac{1}{\beta} \cdot \omega$$

$$V = \frac{\omega}{\beta} = \frac{\omega}{\omega\sqrt{LC}} = \frac{1}{\sqrt{LC}}$$

$$\boxed{V = \frac{1}{\sqrt{LC}}}$$

★ Distortion Line

When the received signal is always having noise and this signal is called distorted line.

It has two types :- i) Frequency dis. line
ii) Phase dis. line

Freq. distortion is due to variation of attenuation constant α.

$$\alpha = \sqrt{\frac{RG - \omega^2 LC + \sqrt{(RG - \omega^2 LC) + \omega^2 (LG + RC)^2}}{2}}$$

Phase distortion is due to variation of phase constant β.

$$\beta = \sqrt{\frac{1}{2}\sqrt{(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2) - (RG - \omega^2 LC)}}$$

★ Distortionless Line

The line in which there is no phase and freq. distortion is called distortion-less line.

It is also represented β.

$$\beta = \sqrt{\frac{(\omega^2 LC - RG) + \sqrt{(RG - \omega^2 LC)^2 + \omega^2 (LG + RC)^2}}{2}}$$

If the transmission line is distortionless line the 2nd term is equal to $(RG + \omega^2 LC)^2$.

$$(RG - \omega^2 LC)^2 + \omega^2 (LG + RC)^2 = (RG + \omega^2 LC)^2$$

$$\cancel{R^2 G^2} + \cancel{\omega^4 L^2 C^2} - 2RG\omega^2 LC + \omega^2 L^2 G^2 + \omega^2 R^2 C^2 + \cancel{2\omega^2 LGRC} = \cancel{R^2 G^2} + \cancel{\omega^4 L^2 C^2} + 2RG\omega^2 LC$$

$$\Rightarrow \omega^2 L^2 G^2 + \omega^2 R^2 C^2 - 2RG\omega^2 LC = 0$$

$$\Rightarrow \omega^2 (LG - RC)^2 = 0$$

$$LG - RC = 0$$

$$LG = RC$$

2 marks

$$\boxed{\frac{G}{C} = \frac{R}{L}}$$

condition for distortionless line

* Telephone Cable

Telephone cable line is insulated with plastic or papers. This construction results the negligible values of inductance and conductance.

- Condition for telephone cable

$\cancel{L\omega \gg R}$ $L\omega \ll R$

and

$G \ll C\omega$

Impedance $Z = R + j\omega L = R$

Admittance $Y = G + j\omega C = j\omega C$

Propagation constant $(\gamma) = \sqrt{ZY}$

$= \sqrt{R j\omega C}$

$= \sqrt{j\omega RC}$

$= \sqrt{\omega RC \angle 90^\circ}$

$= \sqrt{\omega RC} \angle 45^\circ$

$= \sqrt{\omega RC}(\cos 45^\circ + j \sin 45^\circ)$

$= \sqrt{\omega RC}\ \frac{1}{\sqrt{2}} + j\frac{1}{\sqrt{2}}$

th

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45°

45°)

$$\gamma = \sqrt{\omega RC} \cdot \frac{1}{\sqrt{2}}(1+j)$$

$$= \sqrt{\frac{\omega RC}{2}} + j\sqrt{\frac{\omega RC}{2}}$$

comp. with

$$\gamma = \alpha + j\beta$$

$$\alpha = \sqrt{\frac{\omega RC}{2}}$$

$$\beta = \sqrt{\frac{\omega RC}{2}}$$

Velocity propagation of tetephone cable

$$V = \frac{\omega}{\beta} = \frac{\omega}{\sqrt{\frac{\omega RC}{2}}} = \sqrt{\frac{2\omega}{RC}}$$

characteristic impedance $Z_0 = \sqrt{\frac{Z}{Y}}$

$$Z_0 = \sqrt{\frac{R}{j\omega C}} = \sqrt{\frac{R\angle -90^\circ}{\omega C}}$$

$$Z_0 = \sqrt{\frac{R}{\omega C}} \angle -45^\circ$$

★ Reflection on a line not terminated in Z_0

If a transmission line is not terminated by Z_0 so the line is open ckt.

i.e. $Z_R = \infty$

$Z_R \to 0$ for short ckt or closed ckt

- General eq for transmission line

$$V = \frac{V_R}{2} \; \cancel{ZRZ} \; \frac{Z_R + Z_0}{Z_R}\left[e^{\gamma l} + \frac{Z_R - Z_0}{Z_R + Z_0} e^{-\gamma l}\right]$$

$$I = \frac{I_R}{2} \; \frac{Z_R + Z_0}{Z_0}\left[e^{\gamma l} - \frac{Z_R - Z_0}{Z_R + Z_0} e^{-\gamma l}\right]$$

Here, line is not terminated by Z_0 so,

$Z_R \neq Z_0$.

So, the current and voltage is consist of two parts

→ Varying exponentially with +ve l.

→ Varying exponentially with −ve l.

The first component of voltage and current varying expo. with +ve l is called as incident wave. It flows from sending into receiving wave.

The 2nd component of voltage and current varying expon. with -ve l called as reflected wave. It flows throu receiving end to sending end.

Seperate the incident and reflected wave from general solution.

$$V_1 = \frac{V_R}{2} \frac{Z_R + Z_0}{Z_R} e^{\gamma l} \quad \text{— (1)} \quad \rightarrow \text{incident wave Voltage}$$

$$V_2 = \frac{V_R}{2} \frac{Z_R - Z_0}{Z_R} e^{-\gamma l} \quad \text{— (2)} \quad \rightarrow \text{reflected wave voltage}$$

$$I_1 = \frac{I_R}{2} \frac{Z_R + Z_0}{Z_0} e^{\gamma l} \quad \text{— (3)} \quad \rightarrow \text{incident wave Current}$$

$$I_2 = \frac{-I_R}{2} \frac{Z_R - Z_0}{Z_0} e^{-\gamma l} \quad \text{— (4)} \quad \rightarrow \text{reflected wave current}$$

If line is open ckt then.

$$Z_R \rightarrow \infty$$

From (1)

$$V_1 = \frac{V_R}{2} \frac{\cancel{Z_R}(1 + Z_0/Z_R)}{\cancel{Z_R}} e^{\gamma l}$$

$$V_1 = \frac{V_R}{2} e^{\gamma l}$$

This wave propagates from sending end to receiving end.

The reflected wave component

$$V_2 = \frac{V_R}{2} e^{-\gamma l}$$

This wave travels from receiving end to sending end.

If the line short ckt $l=0$ the voltage of incident wave and reflected wave are equal i.e.

$$V_1 = V_2 = \frac{V_R}{2}$$

Imp When line is terminated by Z_0 without having any reflection is called <u>smooth line.</u>

★ Insertion loss (I_L)

It is defined as

$$I_L = 10 \log \frac{P_i}{P_o}$$

i.e.

It is the ratio of incident power to the reflected power.

where

P_i = power received from load when connected directly from Source to load.

P_o = power received by the source when the line is inserted b/w Source to load.

★ ~~Filter~~

Unit - 01

FILTERS

Filters

It is the electronics device which is designed to separate and pass or supress a group of signal through a mixer of signals. And it also passes freely a desired band of frequency. While almost suppressed other band of freq.

→ Types of filters

- Active filters

They contains transistor, inducto[r] and op amplifiers.

- Passive filters

They contain resistor, capacitor.

→ Types of active filters

1) Low pass filter

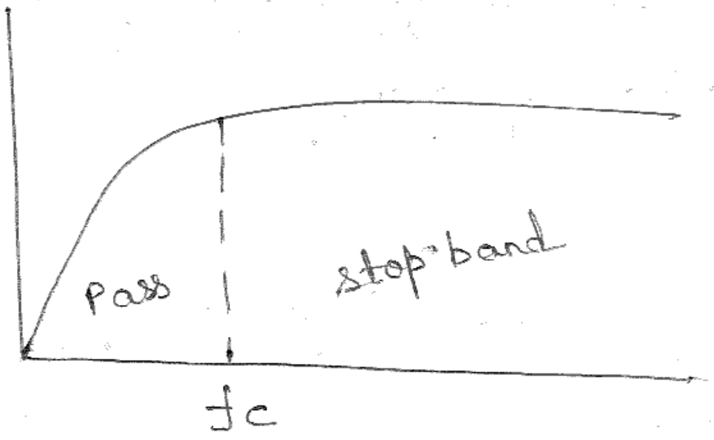
ii) High pass filter

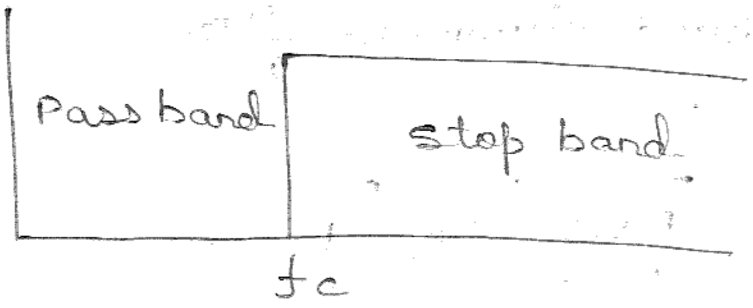
iii) Band pass filter

iv) Band elimination filter

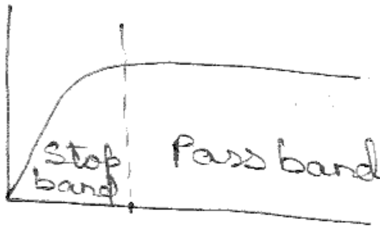
- **Low pass filter**

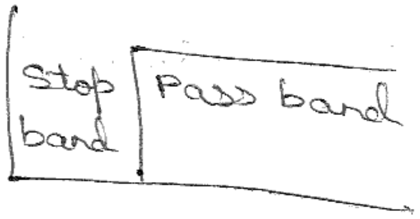
It passes all frequencies upto the cut off frequency. Also attenuates all frequencies above the cut off frequency.





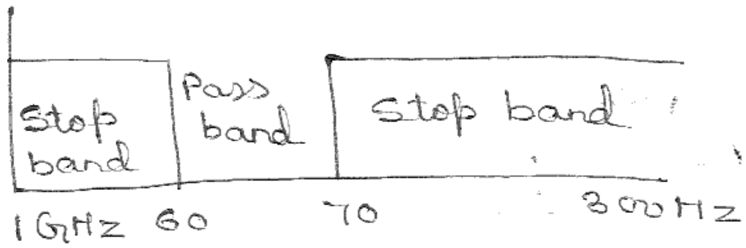
• High pass filter



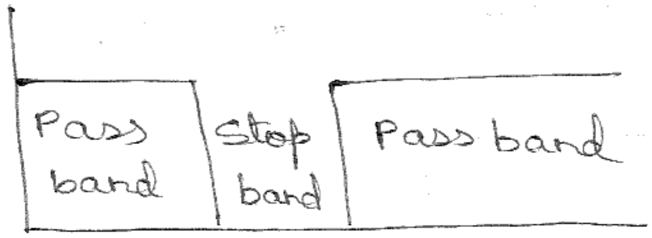


• Band pass filter

The filter passed all the frequencies b/w two cut off frequency and attenuat all other frequency.



• Band elimination filter



* Neper

It is the unit of current to voltage ratio.

or

It is defined as the natural logarithm of input voltage or current to the output voltage or current.

$$\text{Neper} = \ln \frac{V_1}{V_2} \quad \text{or} \quad \ln \frac{I_1}{I_2}$$

cies

enuato

Similarly, the power ratio of any one electrical n/w i.e.

$$\frac{P_1}{P_2} = e^{2N}$$

where

N = Neper

P_1 = i/p power

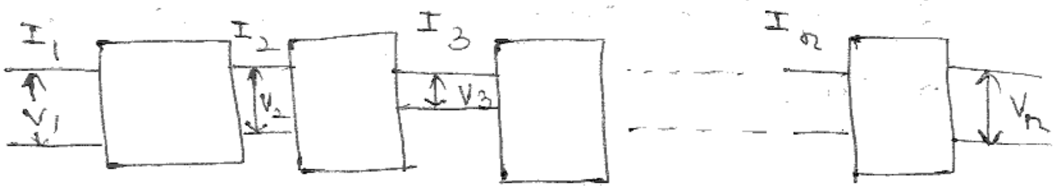
P_2 = o/p power

Take ln both side

$$\ln \frac{P_1}{P_2} = 2N$$

$$\boxed{N = \frac{1}{2} \ln \frac{P_1}{P_2}}$$

Let us assume the cascade n/w



$$N_1 = \ln \frac{V_1}{V_2}$$

$$N_2 = \ln \frac{V_2}{V_3}$$

$$- - - - - - -$$

$$N_n = \ln \frac{V_n}{V_{n+1}}$$

$$N = N_1 + N_2$$

$$N = \ln\left(\frac{V_1}{V_2} \times \frac{V_2}{V_3}\right) = \ln\left(\frac{V_1}{V_3}\right)$$

★ Decibel

It is the 10 times of common logarithm of ratio of i/p power to o/p power.

$$D = 10 \log\left(\frac{P_1}{P_2}\right)$$

where,

P_1 = i/p power

$$\boxed{\ln x = \log_{10} x \times \ln 10}$$

Let $x = \dfrac{P_1}{P_2}$ we get

$$\ln \frac{P_1}{P_2} = \log_{10} \frac{P_1}{P_2} \times \ln 10$$

Put

$$\ln \frac{P_1}{P_2} = 2N$$

$$2N = \frac{D}{10} \times 2.3026$$

$$D = \frac{20N}{2.3026}$$

$$\boxed{D = 8.686\,N}$$

i.e. 1 Decibel $= 8.686$ N

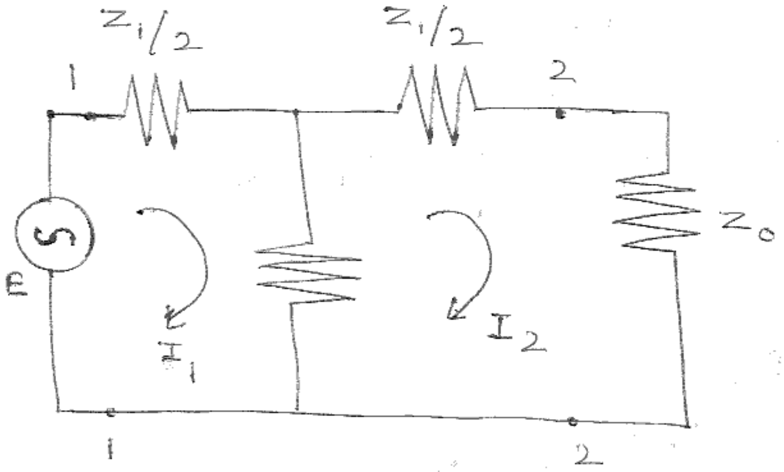
$$N = \frac{1}{8.686} D$$

$$N = 0.115\,D$$

i.e.

$$\boxed{1\,\text{Neper} = 0.115\,D}$$

★ Properties Of Symmetrical Network



$$E = I_1(Z_1/2 + Z_2) - I_2 Z_2 \quad \text{— (1)}$$

2nd loop

$$0 = -I_1 Z_2 + I_2(Z_2 + Z_1/2 + Z_0) \quad \text{— (2)}$$

from eq (2)

$$I_1 Z_2 = I_2(Z_2 + Z_1/2 + Z_0)$$

$$\frac{I_1}{I_2} = \frac{Z_2 + Z_1/2 + Z_0}{Z_2} = e^{\gamma}$$

because

$$\frac{I_1}{I_2} = e^{\gamma}$$

$$\frac{I_1}{I_2} = e^{\gamma} = \frac{Z_1/2}{Z_2} + \frac{Z_0}{Z_2} + 1 \quad \text{— (3)}$$

We know that,

$$Z_0 = \sqrt{\frac{Z_1^2}{4} + Z_1 Z_2} \quad \text{—— (4)}$$

Subti (4) in (3) we get

$$e^{\gamma} = 1 + \frac{Z_1/2}{Z_2} + \frac{\sqrt{Z_1^2/4 + Z_1 Z_2}}{Z_2}$$

$$= 1 + \frac{\frac{Z_1}{2}}{Z_2} + \sqrt{\frac{Z_1^2}{4Z_2^2} + \frac{Z_1}{Z_2}} \quad \text{—— (5)}$$

lly,

$$e^{-\gamma} = 1 + \frac{Z_1/2}{Z_2} - \sqrt{\frac{Z_1^2}{4Z_2^2} + \frac{Z_1}{Z_2}} \quad \text{—— (6)}$$

Adding eq (5) and eq (6)

$$e^{\gamma} + e^{-\gamma} = 2 + 2\,\frac{Z_1/2}{Z_2} = 2\left[1 + \frac{Z_1/2}{Z_2}\right]$$

$$\frac{e^{\gamma} + e^{-\gamma}}{2} = 1 + \frac{Z_1/2}{Z_2}$$

$$\cosh\gamma = 1 + \frac{\frac{Z_1}{2}}{Z_2} \quad \text{—— (7)}$$

Subtracting (5) from (6)

$$e^{\gamma} - e^{-\gamma} = 2\sqrt{\frac{Z_1^2}{4Z_2^2} + \frac{Z_1}{Z_2}}$$

$$= \frac{2}{Z_2}\sqrt{\frac{Z_1^2}{4} + Z_1 Z_2}$$

$$= \frac{2Z_0}{Z_2}$$

$$\frac{e^{\gamma} - e^{-\gamma}}{2} = \frac{Z_0}{Z_2}$$

$$\sinh\gamma = \frac{Z_0}{Z_2} \quad \text{—— (8)}$$

Dividing (8) by (7)

$$\tanh\gamma = \frac{\sinh\gamma}{\cosh\gamma} = \frac{Z_0/Z_2}{1 + \frac{Z_1/2}{Z_2}}$$

$$\tanh\gamma = \frac{Z_0}{Z_2 + \frac{Z_1}{2}}$$

Consider eq (7)

$$\cosh\gamma = 1 + \frac{Z_1/2}{Z_2}$$

$$\cosh\gamma - 1 = \frac{\frac{Z_1}{2}}{Z_2}$$

We know that

$$2\sinh^2\frac{\gamma}{2} = \cosh\gamma - 1$$

$$\therefore\ 2\sinh^2\frac{\gamma}{2} = \frac{\frac{Z_1}{2}}{Z_2}$$

$$\sinh^2\frac{\gamma}{2} = \frac{Z_1/2}{2Z_2}$$

$$\sinh\frac{\gamma}{2} = \sqrt{\frac{Z_1/2}{2Z_2}}$$

Consider eq (8)

$$\sinh\gamma = \frac{Z_0}{Z_2}$$

$$2\sinh\frac{\gamma}{2}\cosh\frac{\gamma}{2} = \frac{Z_0}{Z_2}$$

$$\cosh\frac{\gamma}{2} = \frac{Z_0}{2Z_2 \sinh\frac{\gamma}{2}}$$

$$= \frac{Z_0}{2Z_2}\sqrt{\frac{2Z_2}{\frac{Z_1}{2}}}$$

$$\cosh\frac{\gamma}{2} = \frac{Z_0}{\sqrt{2\frac{Z_1}{2}Z_2}}$$

$$\tanh\frac{\gamma}{2} = \frac{\sinh\frac{\gamma}{2}}{\cosh\frac{\gamma}{2}}$$

$$= \frac{\sqrt{\frac{Z_1/2}{2Z_2}}}{\frac{Z_0}{\sqrt{2\frac{Z_1}{2}Z_2}}}$$

$$= \sqrt{\frac{Z_1/2}{2Z_2}} \times \frac{\sqrt{2Z_{1/2}Z_2}}{Z_0}$$

$$= \sqrt{\frac{Z_1/2 \times 2Z_1/_2 Z_2}{2Z_2 \times Z_0 \times Z_0}}$$

$$\tanh\frac{\gamma}{2} = \frac{\frac{Z_1}{2}}{Z_0}$$