→ TRANSMISSION LINE PARAMETER

⇒ TRANSMISSION LINES :-

- The transform the energy from one point to another take place through either the transmission lines is wave guides
- The electrical lines which are used to transmeeted. The electrical wave to one place to another place.
- Example of transmission line
  i) Telephone cable
  ii) Electrical power signal

⇒ TYPES OF TRANSMISSION LINES :-

1) OPEN WIRE LINE :-

It is made of Alluminium and copper. It is not insulated with any material.

Ex.
i) Telephone line
ii) Electrical power signal line.

2) CABLES :-

These are under ground line. These wire are insulated by plastic or paper.

3) Co-axial Cables :-

It has two conductor one conductor is hollow and other is place co-axially inside in I[st] conductor.

4) WAVE GUIDES :-

This are used to transmitted by micro wave frequence (range 1GHz to 300GHz)

☆ TRANSMISSION LINE PARAMETER

i) Resistance (R)

ii) Capacitance (C)

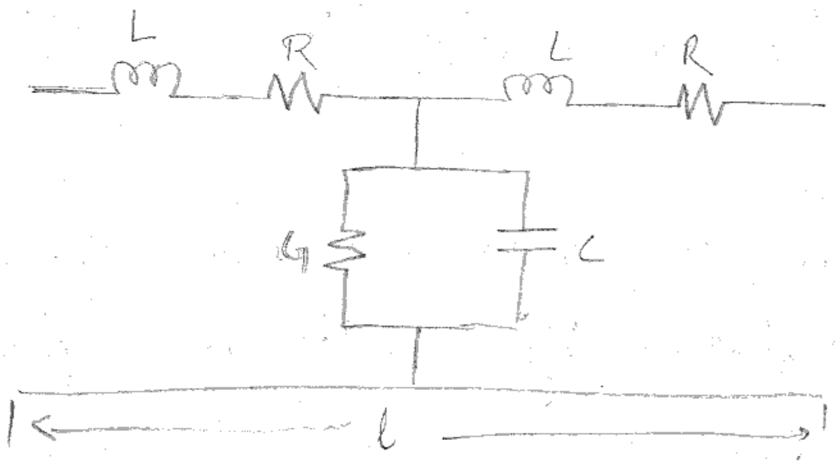
iii) Inductance (L)

iv) Conductance (G)

☆ CHARACTERISTIC IMPEDANCE (Z_0) :-

- Characteristic impedance symmetrial network is the impedance is measured at the input of the first network in the chain of infinite network in cascade.

☆ EQUIVALENT IN CIRCUIT OF TRANSMISSION LINE :-



- The parameter R, L, C & G are distributed throw out the transmission lines. The series impedence of transmission lines is represented by Z

$\Rightarrow \boxed{Z = R + j\omega L}$

- where
  ω - freq. of tr. line

- The shunt admettence

$\Rightarrow \boxed{Y = G + j\omega C}$

$\Rightarrow \boxed{Z_1 = (R + j\omega L)\, l}$

$\Rightarrow \boxed{Y_1 = (G + j\omega C)\, l}$

- we know that

$\Rightarrow Z = 1/Y \qquad \boxed{Z_2 = \frac{1}{Y_1} = \frac{1}{(G + j\omega C)l}}$

- characterstic impedence of total n/w

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

$$\Rightarrow \quad = \sqrt{\frac{(R + j\omega L)^2 l^2}{4} + (R + j\omega L)\cancel{l} \cdot \frac{1}{(G + j\omega C)\cancel{l}}}$$

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

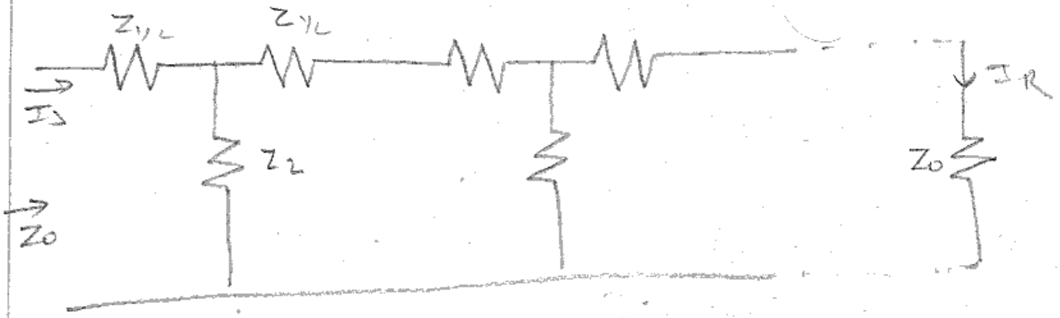
- Let as assume length is very short subsuite the value $l = 0$

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

$$\Rightarrow \boxed{Z_0 = \sqrt{Z/Y}}$$

TRANSMISSION LINE AS CASCADED

T section :-



- $I_s \Rightarrow$ Sending current
- $I_R \Rightarrow$ Receiving current.

$\Rightarrow \boxed{I_s = I_R e^{n\gamma}}$ gamma

Sending current $= I_R e^{n\gamma}$

where
- "n" is no. of network
- γ is propagation constant

$\Rightarrow \boxed{\gamma = \alpha + i\beta}$

- α is attenuation (lost)
- β is phase shift

* The receiving current at first network

$$\Rightarrow I_1 = I_s \times \frac{Z_2}{Z/2 + Z_0 + Z_2}$$

$$\Rightarrow \frac{I_s}{I_1} = \frac{Z/2 + Z_0 + Z_2}{Z_2}$$

We know that

$$\Rightarrow \frac{I_s}{I_R} = e^{n\gamma}$$

for I^{st} network

$$\Rightarrow \frac{I_s}{I_1} = e^{\gamma}$$

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

$$\Rightarrow \frac{I_1}{I_2} = e^{\gamma} = 1 + \frac{Z_0}{Z_2} + \frac{Z_{1/2}}{Z_2}$$

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

$$\Rightarrow \boxed{\frac{I_s}{I_R} = e^{n\gamma}}$$

☆ PROPAGATION CONSTANT (γ) ⇒

» Propagation Constant is defines is the natural logrithmic the ratio of sending end current or voltage receiving end current or voltage

$$\Rightarrow \gamma = \ln \frac{I_s}{I_R} \text{ or } \ln \frac{V_s}{V_R}$$

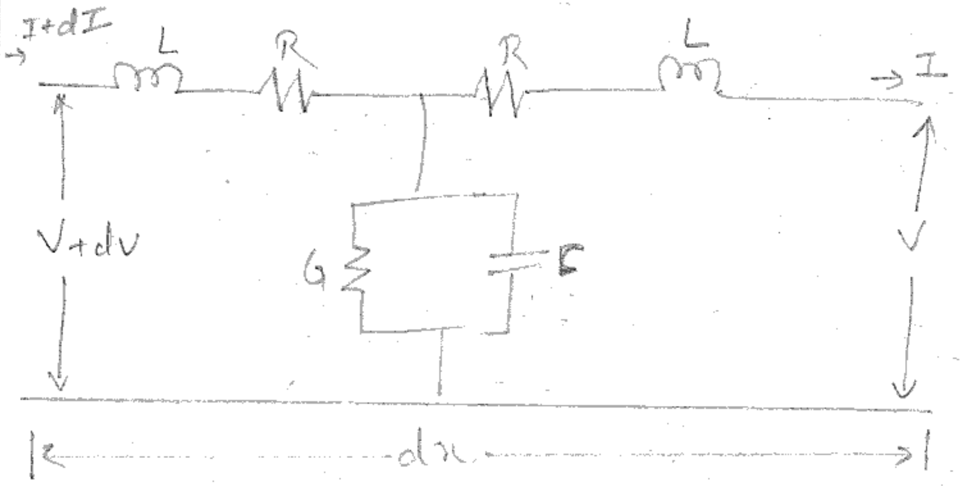
$$\Rightarrow \gamma = \alpha + j\beta$$

also known as

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

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

The General Solution Of Transmission line (Tr. line eq.) :-



- Let assum the current line I+dI

L, R, C & G are tran. line parameters. The series impedence of the trans. line

$\Rightarrow$ $\boxed{Z = (R + j\omega L)}$

- The shunt admittance of the trans line

$\Rightarrow$ $\boxed{Y = (G + j\omega C)}$

- Consider the trans. line is having some distance. This distance is represent as dx. The impedence is

$\Rightarrow$ $\boxed{Z = (R + j\omega L)\,dx}$

and shunt admitance is

$\Rightarrow$ $\boxed{Y = (G + j\omega C)\,dx}$

- Consider V+dv is i/p voltage of the trans. line and I + dI is input current of the trans. line.

- V, I is the output voltage & current of the trans. line
- The potaintial (voltage) difference b/w two end (i/p into o/p).

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

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

$$\Rightarrow \boxed{\frac{dv}{dx} = IZ} \quad \text{--- (1)}$$

- The current difference in i/p end into output end.

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

$$\Rightarrow \boxed{\frac{dI}{dx} = VY} \quad \text{--- (2)}$$

- Diff. eq^n (1) with respect to x

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

$$\Rightarrow \boxed{\frac{d^2I}{dx^2} = (R + j\omega L)(G + j\omega C)\,V} \quad \text{--- (3)} \quad [\because \text{from eq}^n\ 2]$$

- Similarly diff. eq^n (2) with r. to x

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

$$\Rightarrow \boxed{\frac{d^2I}{dx^2} = (G + j\omega C)(R + j\omega L)\,I} \quad \text{--- (4)} \quad \because [\text{from eq}^n\ 1]$$

- We already know that the propagation gamma constant

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

- The potaintial (voltage) difference b/w two end (i/p into o/p).

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

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

$$\Rightarrow \boxed{\frac{dv}{dx} = IZ} \text{ ——— } (1)$$

- The current difference in i/p end into output end.

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

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- Diff. eq^n (1) with respect to x

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

$$\Rightarrow \boxed{\frac{d^2I}{dx^2} = (R + j\omega L)(G + j\omega C)\,V} \text{ ——— } (3) \quad [\because \text{from eq}^n\ 2]$$

- Similarly diff. eq^n (2) with r. to x

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

$$\Rightarrow \boxed{\frac{d^2I}{dx^2} = (G + j\omega C)(R + j\omega L)\,I} \text{ ——— } (4) \quad \because [\text{from eq}^n\ 1]$$

- We already know that the propagation gamma constant

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

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

Sub. the value of gamma in eq^n (3) & eq^n (4)

$\left\{\because \text{Let } \frac{d^2V}{dx^2} = m = \frac{d^2I}{dx^2}\right\}$

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

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

$$m = \pm \gamma$$

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

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

$$m = \pm \gamma$$

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

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

where
A, B, C & D is are arbitray constant

Diff. eq^n (5) w.r. to x

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

from eq^n (1) $\frac{dv}{dx} = IZ$

$$IZ = A\gamma e^{\gamma x} - B\gamma e^{-\gamma x}$$

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

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

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

Similarly diff. eq^n (6) w.r.t. to x

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

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

If the trans. line is short $x = 0$

and replace the value $I = I_R$, $V = V_R$

This condistion applying to eq^n (5) & (6)

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

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

$\left[\begin{array}{l} \because x = 0 \\ e^{\gamma x} = e^0 = 1 \end{array} \right]$

Same condition should apply eq^n (7) & (8)

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

$$\boxed{V_R = C\sqrt{Z/Y} - D\sqrt{Z/Y}} \quad (12)$$

Let as assume $\sqrt{Z/Y} = x$

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

~~rep~~

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

Compair above eq^n with eq^n (10)

$$C + D = \frac{1}{x}(A - B)$$

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

Similarly

V_R ... $Cx - Dx$

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

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

If the trans. line is short $x = 0$

and replace the value $I = I_R$, $V = V_R$

This condistrion applying to eq^n (5) & (6)

$$\boxed{V_R = A + B} \quad \text{— (9)} \qquad \left\{ \begin{array}{l} \text{let } x = 0 \\ \therefore e^{\gamma x} = e^0 = 1 \end{array} \right\}$$

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

Same condition should apply eq^n (7) & (8)

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

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

Let as assume $\sqrt{Z/Y} = x$

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

~~rep~~

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

Compair above eq^n with eq^n (10)

$$C + D = \frac{1}{x}(A - B)$$

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

Similarly

$$V_R = Cx - Dx$$

» Compair above eqⁿ with eqⁿ (9)

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

$$\Rightarrow \boxed{A-B = Cx + Dx}$$

» adding eqⁿ (13) and (14)

$$\Rightarrow 2A = 2Cx$$

$$\Rightarrow A = Cx$$

» Substracting eqⁿ (13) and (14)

$$\Rightarrow 2B = -2Dx$$

$$\Rightarrow B = -Dx$$

» Sub the value of A & B in eqⁿ (9)

$$\Rightarrow \boxed{V_R = Cx - Dx} \text{ ——— (15)}$$

• from (10)

$$\Rightarrow I_R = C + D$$

» multiplying bn x in eqⁿ (1?)

$$\Rightarrow \boxed{I_R x = Cx + Dx} \text{ ——— (16)}$$

» Should the add eqⁿ (15) and (16)

$$\Rightarrow V_R + I_R x = 2Cx$$

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

$$\Rightarrow \boxed{C = \frac{I_R}{2} + \frac{V_R}{2}\sqrt{Y/Z}} \text{ ——— (17)}$$

» Substracting the eqⁿ (15) and (16)

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

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

$\Rightarrow \boxed{A + B = Cx - Dx}$ —— 14

$\Rightarrow \boxed{A - B = Cx + Dx}$

- adding eqⁿ 13 and 14

$\Rightarrow 2A = 2Cx$

$\Rightarrow A = Cx$

- Substracting eqⁿ 13 and 14

$\Rightarrow 2B = -2Dx$

$\Rightarrow B = -Dx$

- Sub. the value of A & B in eqⁿ 9

$\Rightarrow \boxed{V_R = Cx - Dx}$ —— 15

- from 10

$\Rightarrow I_R = C + D$

- multiplying bn x in eqⁿ 10

$\Rightarrow \boxed{I_R x = Cx + Dx}$ —— 16

- Should the add eqⁿ 15 and 16

$\Rightarrow V_R + I_R x = 2Cx$

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

$\Rightarrow \boxed{C = \frac{I_R}{2} + \frac{V_R}{2}\sqrt{Y/Z}}$ —— 17

- Substracting the eqⁿ 15 and 16

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

$\Rightarrow 2Dx = I_R x - V_R$

$\Rightarrow \boxed{D = \frac{I_R}{2} - \frac{V_R}{2}\sqrt{Y/Z}}$ —— 18

$$\Rightarrow \quad A = Cx$$

$$\Rightarrow \quad A = \frac{I_R}{2} + \frac{V_R}{2x} \cdot x$$

$$\Rightarrow \quad \boxed{A = \frac{V_R}{2} + \frac{V_R}{2}\sqrt{Z/Y}} \quad \text{—— (19)}$$

$$\Rightarrow \quad B = -Dx$$

$$\Rightarrow \quad B = -\frac{I_R x}{2} + \frac{V_R}{2x} \cdot x$$

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

- The characteristic impedent

$$\Rightarrow \quad Z_0 = \sqrt{Z/Y}$$

- from ohm's law

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

$$\Rightarrow \quad Z_0 = \sqrt{Z/Y}$$

$$\Rightarrow A = \frac{V_R}{2} + \frac{I_R}{2}\sqrt{Z/Y}$$

$$\Rightarrow \quad = \frac{V_R}{2} + \frac{V_R}{2Z_R} \cdot Z_0 \qquad \left\{\because I_R = \frac{V_R}{Z_R}\right\}$$

$$\Rightarrow \quad \boxed{A = \frac{V_R}{2}\left(1 + \frac{Z_0}{Z_R}\right)} \quad \text{—— (21)}$$

$$\Rightarrow B = \frac{V_R}{2} - \frac{I_R}{2}\sqrt{Z/Y}$$

$$\Rightarrow \boxed{B = \frac{V_R}{2}\left(1 - \frac{Z_0}{Z_R}\right)} \quad \text{—— (22)}$$

$$\Rightarrow \quad C = \frac{I_R}{2} + \frac{V_R}{2}\sqrt{Y/Z}$$

$$\Rightarrow \quad C = \frac{I_R}{2} + \frac{I_R Z_R}{Z_0} \qquad \{\because V_R = I_R Z_R\}$$

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

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

- Substitude the value of A, B, C, D in eq^n (5) & (6)

$$\Rightarrow \boxed{V = \frac{V_R}{2}\left(1 + \frac{Z_0}{Z_R}\right) e^{\gamma x} + \frac{V_R}{2}\left(1 - \frac{Z_0}{Z_R}\right) e^{-\gamma x}} \quad (25)$$

$$\Rightarrow \boxed{I = \frac{I_R}{2}\left(1 + \frac{Z_R}{Z_0}\right) e^{\gamma x} + \frac{I_R}{2}\left(1 - \frac{Z_R}{Z_0}\right) e^{-\gamma x}} \quad (26)$$

- from eq^n (25)

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

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

$$\{\because V_R = I_R Z_R\}$$

$$\Rightarrow \boxed{V = V_R \cosh \sqrt{ZY}\,x + I_R Z_0 \sinh \sqrt{ZY}\,x} \quad (27)$$

- from eq^n (26)

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

$$\Rightarrow \boxed{I = V_R \cosh \sqrt{ZY}\,x + \frac{V_R}{Z_0} \sinh \sqrt{ZY}\,x} \quad (28)$$

$\Rightarrow$ eq^n (27) & (28) are general solution of transmission lines.

THE PHYSICAL SIGNIFICANCE OF GENERAL

Sol^n :-

SENDING IMPEDENCE :-

It is the ratio of sending voltage & sending current

$$Z_S = \frac{V_s}{I_s}$$

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

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

V_R is replace by $I_R Z_R$

$$V_s = I_R Z_R \cosh \gamma l + I_R Z_0 \sinh \gamma l$$

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

dividing above equ

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

Condition Ist :-

When the line is terminated the $Z_R = Z_0$

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

$$\Rightarrow \boxed{Z_s = Z_0}$$

Condition IInd :-

The trans. line is infinite length here

$l = \infty$

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

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

Put $l = \infty$

$$= Z_0 \frac{Z_R + Z_0 \tan \infty}{Z_0 + Z_R \tan \infty}$$

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

$$\boxed{Z_s = Z_0}$$

REFLECTION CO-EFFICIENT :-

This is depends as the ratio of reflected voltage to the incident voltage (i/p voltage) at the receiving end denote by K

$$K = \frac{\text{Reflected voltage}}{\text{incident voltage}} = \frac{V_R}{V_s}$$

The general voltage eq^n of trans. line from eq^n (25)

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

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

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

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

The second term $e^{-\gamma x}$ is represent the 'reflected wave'.

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

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

It is also defined as in the terms of the ratio of reflected current to the incident current. But it is negative

$$\boxed{K = \frac{-I_R}{I_S}}$$

If the trans. line is termined by characterstick impedence $Z_R = Z_0$ at that time reflected co-efficient become zero.

WAVE LENGTH & VELOCITY PROPAGATION

$\lambda = v/f$

WAVE LENGTH

The distance traveled by the wave along the line which the ~~face~~ phase angle is changing through '$2\pi R$' is called wave length.

$$\beta\lambda = 2\pi$$
$$\lambda = \frac{2\pi}{\beta} \qquad \left\{\beta = \frac{2\pi}{\lambda}\right\}$$

VELOCITY PROPAGATION:-

We know that the propagation gamma constant is equal to

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

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

squaring both side

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

$\Rightarrow \gamma^2 = RG + Rj\omega L + jG\omega L - \omega^2 LC$

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

Condition Ist $\Rightarrow$

Here minimum attanuation in 'L'

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

$$LG = RC$$

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

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

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

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

$\alpha = \sqrt{RG}$

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

The velocity propagation is given by

$V = \lambda f$

multiple and divided by 2π

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

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

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

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

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DISTORTION LINE :-

When the ~~receiving~~ signal is always having noise in this received signal is called as distorted line.

It has two types.

i) Freq. distortion line

ii) Phase " "

1) FREQUENCY DISTORTION LINE :-

Frequency distortion due to the variation of attenuation constant α

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

2) PHASE DISTRORTION LINE :-

It is due to the variation of phase constant β.

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

DISTORTION LESS LINE :-

A line in which their is no phase and frequency distortion. It is known as distortion less line.

Condition Ist :-

It alway represent by β

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

$$= (RG+\omega^2LC)^2$$

If the tran. line is distortion less line the second term is

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

$$\Rightarrow R^2G^2+\omega^4L^2C^2-2RG\omega^2LC+\omega^2L^2G^2+R^2C^2\omega^2+2\omega^2LGRC$$

$$= \omega^4L^2C^2+R^2G^2+2\omega^2LCRG$$

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

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

$$\Rightarrow LG-RC=0$$

$$\Rightarrow LG=RC$$

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

TELEPHONE CABLE :

It is line insulated with plastic or paper this construction result the negligible value of indectance and conductance (L & G).

CONDITION FOR TELEPHONE CABLE :-

Lω is very much less than reasistance

$$\boxed{L\omega << R}$$

& $\boxed{G << C\omega}$

So the impedence Z is equal to $R+j\omega L$

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

The admittence

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

The propagation of constant of telephone cable.

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

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

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

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

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

already we know that

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

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

The velocity of propagation of telephone cable

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

characterstic impedence of telephone cable.

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

$$Z_0 = \sqrt{R/j\omega C}$$

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

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