Institute of Engineering
Jiwaji University

Unit- IV BE IV Sem

Transmission Line Analogy (Part-I)

EL-402 ELECTRONICS

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Topic – Transmission Lines

Introduction :- Transmission lines are used to transmit electric energy and signals from one point to another specially from a source to ~~Lod~~ Load.

Ex:- hydrogeneratic plant, Stereo System, Cable service provider and T.V set.

In short some examples for higher frequencies as devices on a circuit board are less familiar.
Negligible length
Time delay (distances large)

Note: Wave phenomena on transmission lines, we have point-to-point energy propagation in free space or in dielectrics.

Network :-

1) Lumped Network → The basic element in the circuit resistor, capacitors, inductors and the connection between them. They are considered lumped elements if the time delay in the traversing the elements is negligible.

2) Distributed Network → If the interconnections are large enough.
They (resitive, capacitive and inductive

characteristics must be evaluated on per-unit-distance basis.

TRANSMISSION-LINE EQUATIONS →

The differential equations which the voltage or current must satisfy on a uniform transmission line.

Methods :-

i) Maxwell's equations subject to the boundary conditions imposed by the particular transmission line.

2) TEM-wave problem once and for all for any two-conductors transmission line having lossless conductors.

Voltage & Current Equation →

The inductance, capacitance, shunt conductance and series resistance associated with an incremental length of line.

Let us do assume in terms of a coaxial transmission line containing a dielectric of permeability μ, permittivity ϵ', and conductivity σ. The inner and outer conductors have a high conductivity σ_c.

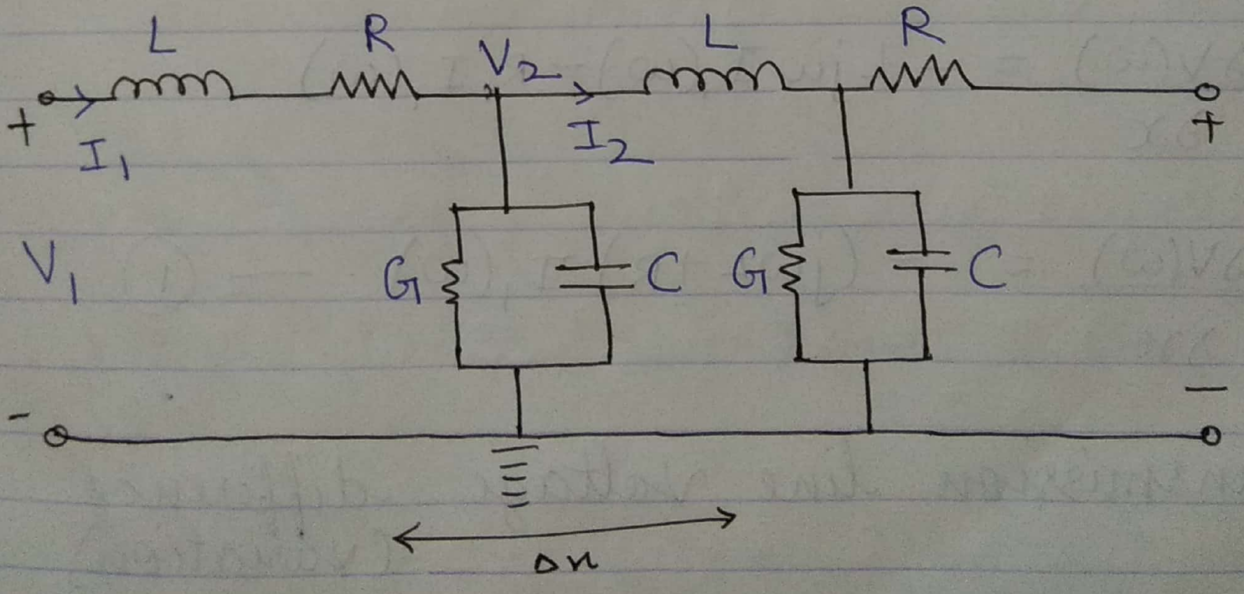
Let us again assume propagation in the a_z direction. Cut out a section of length Δz containing a resistance $R\Delta z$, an inductance $L\Delta z$, a conductance $G\Delta z$, and a capacitance $C\Delta z$.

The voltage V between conductors is in general a function of z and t, as

$$V(z,t) = V_0 \cos(\omega t - \beta z + \psi)$$

We may use Euler's identity to express this in complex notation,

$$V(z,t) = Re\{V_0 e^{j(\omega t - \beta z + \psi)}\}$$
$$= Re\{V_0 e^{j\psi} e^{-j\beta z} e^{j\omega t}\} \quad \text{— (A)}$$



$$\Delta V = V_2 - V_1$$
$$\Delta I = I_2 - I_1$$

Voltage - Equation

$$V_2 = V_1 - L\Delta x \frac{dI_1}{dt} - R\Delta x I_1$$

$\Delta V \Rightarrow$

$$V_2 - V_1 = -L\Delta x \frac{dI_1}{dt} - R\Delta x I_1$$

$$\frac{\Delta V}{\Delta x} = -L\frac{dI_1}{dt} - RI_1$$

$$\frac{\partial V}{\partial x} = -L\frac{dI_1}{dt} - RI_1$$

Laplace transformation

$$\frac{\partial V(s)}{\partial x} = -LSI_1(s) - RI_1(s)$$

$$\frac{\partial V(\omega)}{\partial x} = -Lj\omega I_1(\omega) - R_1 I_1(\omega)$$

$$\frac{\partial V(\omega)}{\partial x} = -(j\omega L + R) I_1(\omega) \quad \text{--- } (1)$$

* Transmission line voltage difference (variation) with respect to distance.

$$\frac{\partial V(\omega)}{\partial x} = -(j\omega L + R)\, I_1(\omega) \quad - (1)$$

$I_1 = I$
$V_1 = V$

$$\frac{\partial V}{\partial x} = -(j\omega L + R) I$$

$\Delta \sim 0$

$I_1 \approx I_2$

$V_1 \approx V_2$

$$\boxed{\frac{\partial V}{\partial x} = -(R + j\omega L) I} \quad - (1)$$

$$= -ZI$$

Rate of change of voltage w.r.t to distance in terms of current.

Current Equation

$$I_1 - I_C = V_2 G \Delta x + C \Delta x \frac{dV_2}{dt}$$

$$-\Delta I = \left(V_2 G + C \frac{dV_2}{dt}\right) \Delta x$$

$VG = I$

$I = C\frac{dV}{dt}$

$$\frac{\Delta I}{\Delta x} = -\left(V_2 G + C\frac{dV_2}{dt}\right)$$

$$\frac{\partial I(\omega)}{\partial x} = -(V_2(\omega) G + j\omega C V_2(\omega)]$$

$$\frac{\partial I(\omega)}{\partial x} = -(G + j\omega C) V_2(\omega)$$

$$\boxed{\frac{\partial I}{\partial x} = -(G + j\omega C) V} \quad - (2)$$

$$= -YV$$

Propagation Constant :-

$$\frac{\partial^2 V}{\partial x^2} = -(R+j\omega L)\frac{\partial I}{\partial x}$$

$$= -(R+j\omega L) - (G+j\omega C)V$$

$$\frac{\partial^2 V}{\partial x^2} = (R+j\omega L)(G+j\omega C)V$$

$$\frac{\partial^2 V}{\partial x^2} = \gamma^2 V$$

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

γ = propagation constant

Attenuation Constant & Phase Constant

$$\frac{\partial^2 I}{\partial x^2} = (R+j\omega L)(G+j\omega C)I$$

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

$$= \alpha + j\beta$$

α = Attenuation Constant

β = Phase Constant