ELC N205: Electromagnetics 1 Tutorials

Department of Communications and Computer Engineering

Introduced By:

Eng. Mohamed Ossama Ashour
E-mail: vert4231@gmail.com

Fall 2020

Agenda

- Transmission Lines
- Parallel-Plate Transmission Lines
- TL theory
- Telegrapher's equations & its solutions
- Distributed Parameters for different TLs
- Transmission Line types

Transmission Lines

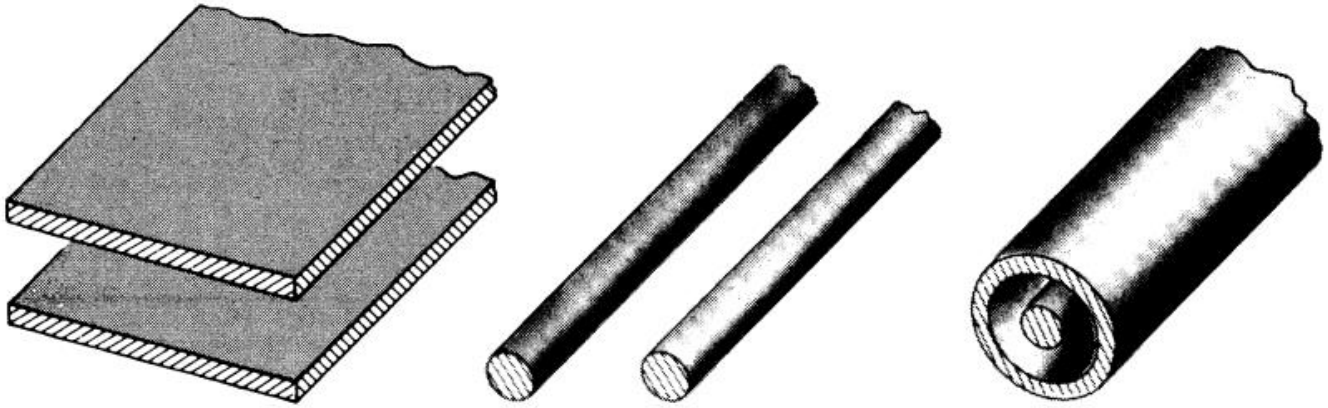
Definition

They are mediums (systems of conductors and dielectrics) capable of confining (guiding) Electromagnetic energy within them.

Types

1) Support TEM Waves

2) Not support TEM Waves



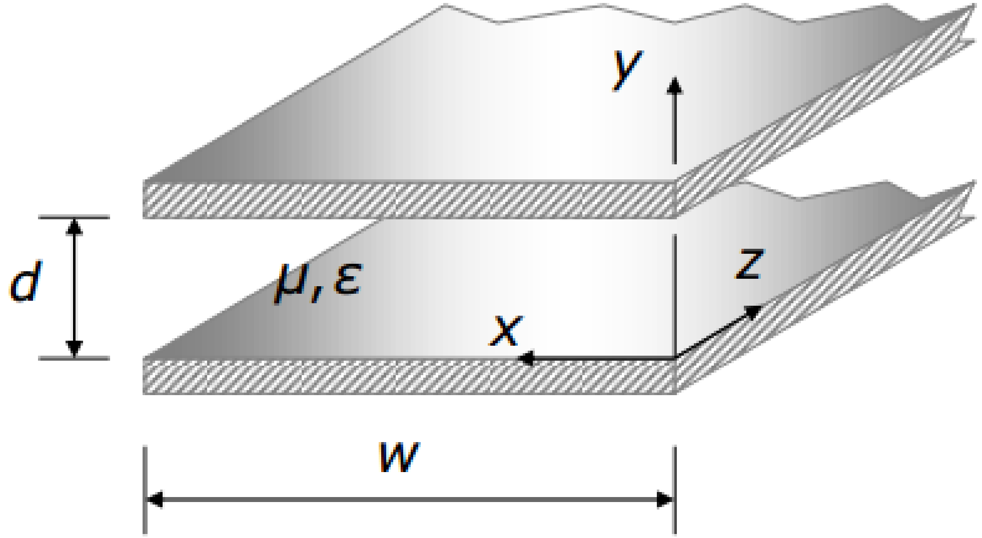
(a) Parallel-plate transmission line. (b) Two-wire transmission line. (c) Coaxial transmission line.

Parallel-Plate Transmission Line

$$\underline{E}(z) = E_o\, e^{-j\beta z}\,\underline{u}_y \qquad \underline{H}(z) = -\frac{E_o}{\eta} e^{-j\beta z}\,\underline{u}_x$$

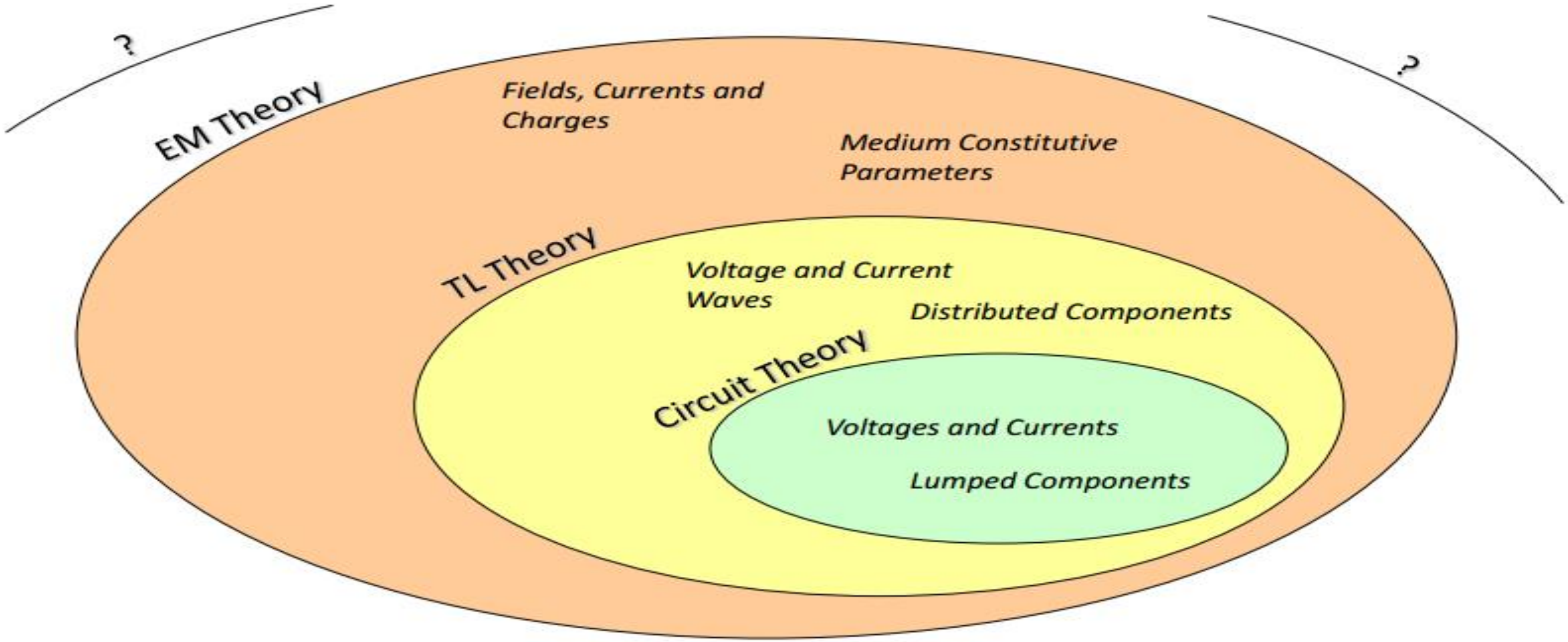
$$\rho_{sl}(z) = \varepsilon E_o\, e^{-j\beta z} \qquad \underline{J}_{sl} = \frac{E_o}{\eta} e^{-j\beta z}\,\underline{u}_z$$

$$\rho_{su}(z) = -\varepsilon E_o\, e^{-j\beta z} \qquad \underline{J}_{su} = -\frac{E_o}{\eta} e^{-j\beta z}\,\underline{u}_z$$



$$\beta = \omega\sqrt{\mu\varepsilon} \qquad \eta = \sqrt{\frac{\mu}{\varepsilon}}$$

TL theory


?
?
EM Theory
Fields, Currents and Charges
Medium Constitutive Parameters
TL Theory
Voltage and Current Waves
Distributed Components
Circuit Theory
Voltages and Currents
Lumped Components

Telegrapher's equations & its solutions

$$\frac{dV(z)}{dz} = -(R + j\omega L)I(z)$$

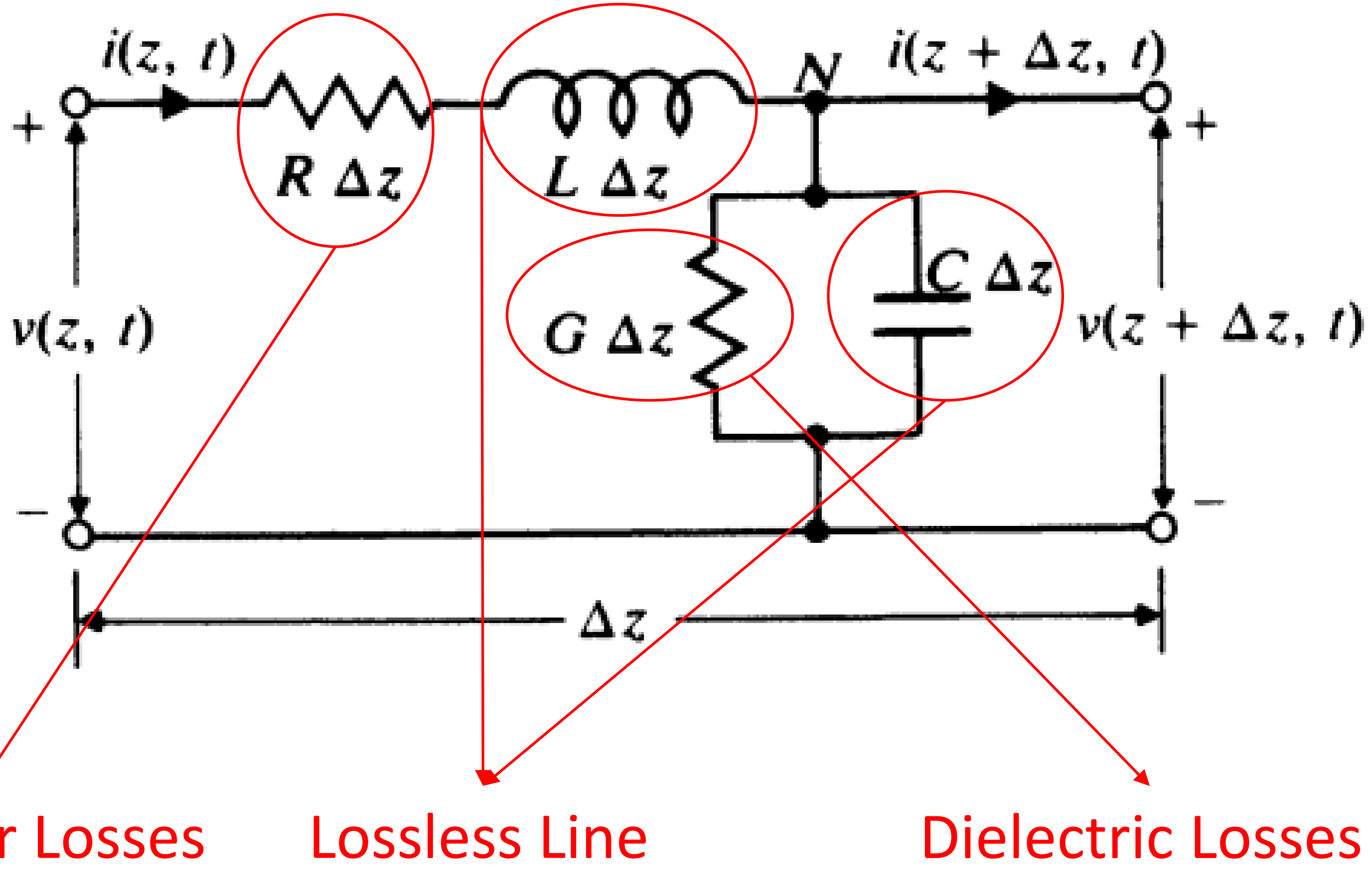
$$\frac{dI(z)}{dz} = -(G + j\omega C)V(z)$$

$$V(z) = V^+(z) + V^-(z)$$

$$= V_0^+ e^{-\gamma z} + V_0^- e^{+\gamma z}$$

$$I(z) = I^+(z) - I^-(z)$$

$$= \frac{1}{Z_0}\left(V_0^+ e^{-\gamma z} - V_0^- e^{+\gamma z}\right)$$



Distributed Parameters for different TLs

Parameter	parallel plate Line	Coaxial Line	Unit
R	$\frac{2}{w}\sqrt{\frac{\pi f \mu_c}{\sigma_c}}$	$\frac{R_s}{2\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$	Ω/m
L	$\mu\frac{d}{w}$	$\frac{\mu}{2\pi}\ln\frac{b}{a}$	H/m
G	$\sigma\frac{w}{d}$	$\frac{2\pi\sigma}{\ln(b/a)}$	S/m
C	$\epsilon\frac{w}{d}$	$\frac{2\pi\epsilon}{\ln(b/a)}$	F/m

$$LC = \mu\epsilon$$

$$\frac{G}{C} = \frac{\sigma}{\epsilon}$$

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

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

Transmission Line types

Lossless

$$R = G = 0$$

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

$$\alpha = 0$$

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

Low Loss

$$R \ll \omega L, G \ll \omega C$$

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

$$\alpha \approx \frac{1}{2}\left(\frac{R}{Z_0} + GZ_0\right)$$

$$Z_0 \approx \sqrt{\frac{L}{C}} - j\sqrt{\frac{L}{C}}\frac{1}{2\omega}\left(\frac{R}{L} - \frac{G}{C}\right)$$

Distortionless

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

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

$$\alpha = \frac{R}{Z_0} = GZ_0$$

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

Exercise V

1) **P.9–4** Consider a transmission line made of two parallel brass strips—$\sigma_c = 1.6 \times 10^7$ (S/m)—of width 20 (mm) and separated by a lossy dielectric slab—$\mu = \mu_0$, $\epsilon_r = 3$, $\sigma = 10^{-3}$ (S/m)—of thickness 2.5 (mm). The operating frequency is 500 MHz.

a) Calculate the R, L, G, and C per unit length.

b) Find γ and Z_0.

2) **P.9–9** The following characteristics have been measured on a lossy transmission line at 100 MHz:

$$Z_0 = 50 + j0 \quad (\Omega),$$
$$\alpha = 0.01 \quad (\text{dB/m}),$$
$$\beta = 0.8\pi \quad (\text{rad/m}).$$

Determine R, L, G, and C for the line.