## Transmission line:

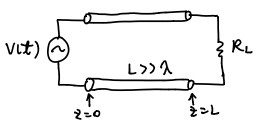
Def: A transmission line is a structure of conductors for guiding EM waves from one pt. to another

wave convey:

① power ex. power line

② signal ex. Twisted pair coax PCB Traces

## Circuit Theory vs. Transm. line Theory:




$V(z=0) \neq V(z=L)$

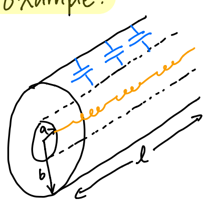
### Circuit Theory:

- Assumes the dimensions of the circuit are <u>small</u> compared to the λ.
- For a sinusoidal source V(z) does <u>not</u> change w z.

### Trans. Line Theory:

- L is not << λ. rules of thumb $\boxed{L > 0.1\lambda}$
- magnitude & phase of V(z) change w z
- KVL & KCL do NOT apply when solving Trans. line problems.

### Example:




<u>Capacitance:</u>

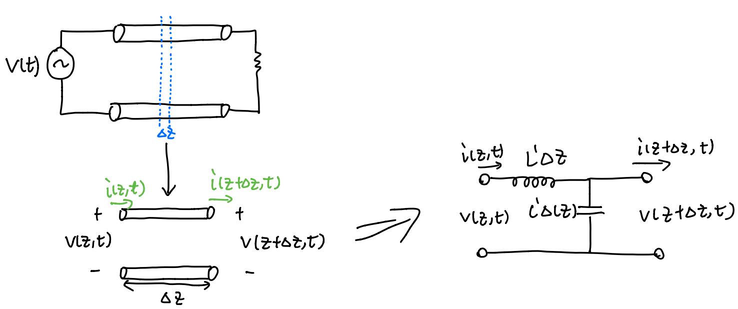
$C = \frac{2\pi l \varepsilon}{\ln(b/a)}$ [F]

$C' = \frac{C}{l} = \frac{2\pi\varepsilon}{\ln(b/a)}$ [F/m]

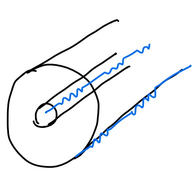
<u>Inductance:</u>

$L = \frac{\mu l}{2\pi}\ln(b/a)$ [H]

$L' = \frac{\mu}{2\pi}\ln(b/a)$ [H/m]



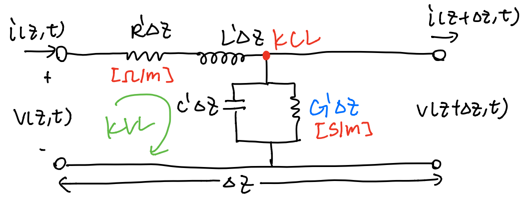

### Losses:



resistor

dilectics

## Complete model:




KVL: $-v(z,t) + R'\Delta z \cdot i(z,t) + L'\Delta z \frac{di(z,t)}{dt} + v(z+\Delta z) = 0$

$$\lim_{\Delta z \to 0} \frac{v(z+\Delta z,t)}{\Delta z} - \frac{v(z,t)}{\Delta z} = -R' i(z,t) - L' \frac{di(z,t)}{dt}$$

$$\boxed{\frac{dv(z,t)}{dz} = -R' i(z,t) - L' \frac{di(z,t)}{dt}} \quad ①$$

Telegrapher's Equation

KCL: $i(z,t) - i(z+\Delta z,t) - G'\Delta z\, v(z+\Delta z,t) - C'\Delta z \frac{dv(z+\Delta z,t)}{dt} = 0$

$$\boxed{\frac{di(z,t)}{dz} = -G' v(z,t) - C' \frac{dv(z,t)}{dt}} \quad ②$$

Oliver Heaviside

## Solving Telegrapher's Equations:

- Use phasors

$$e(t) = -Ri(t) - L\frac{di}{dt} + \frac{1}{C}\int i\,dt$$

$$e(t) = E_0 \cos(\omega t)$$

$$i(t) = I_0 \cos(\omega t)$$

$$i(t) = I_0 \cos(\omega t + \phi)$$

$$= Re\{(I_0 e^{i\phi}) \cdot e^{j\omega t}\}$$

$$= Re\{I_s \cdot e^{j\omega t}\}$$

## phasor:

$$\frac{di(t)}{dt} = \frac{d}{dt} Re\{I_s e^{j\omega t}\}$$

$$= Re\{\frac{d}{dt}(I_s e^{j\omega t})\}$$

$$= Re\{j\omega I_s e^{j\omega t}\}$$

$$\boxed{\frac{di(t)}{dt} = j\omega I_s}$$

$$\int i(t)dt = \int Re\{I_s e^{j\omega t}\}$$

$$= Re[\int I_s e^{j\omega t}\}$$

$$\boxed{\int i(t)dt = \frac{I_s}{j\omega}}$$

$$e(t) = -Ri(t) - L\frac{di(t)}{dt} + \frac{1}{C}\int i\,dt$$

$\downarrow$ phasors

$$E_s = -RI_s - Lj\omega I_s + \frac{1}{C}\frac{1}{j\omega} I_s$$

$$= -(R + j\omega L - \frac{1}{j\omega C}) I_s$$