Fields and Waves

Lesson 4.1

Introduction to TRANSMISSION LINES

Transmission Line

Fundamental Purpose of TL → Transfer signal/power from A to B

EXAMPLES:

- Power Lines (60Hz)
- Coaxial Cables
- Twisted Pairs
- Interconnects (approximates a parallel plate capacitor)

- All have two conductors

Transmission Line Effects

RELEVANT EFFECTS:

- Time Delays
- Reflections/Impedance Matching

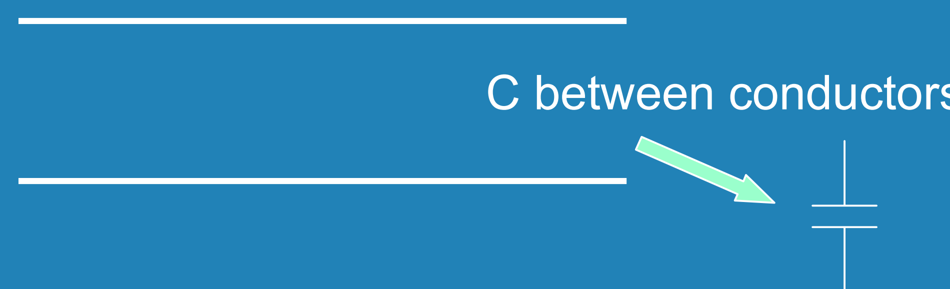
TL effects more important at high ***f*** (or short ***t***) and long lengths

$\vec{E}$ and $\vec{H}$ effects are important for understanding

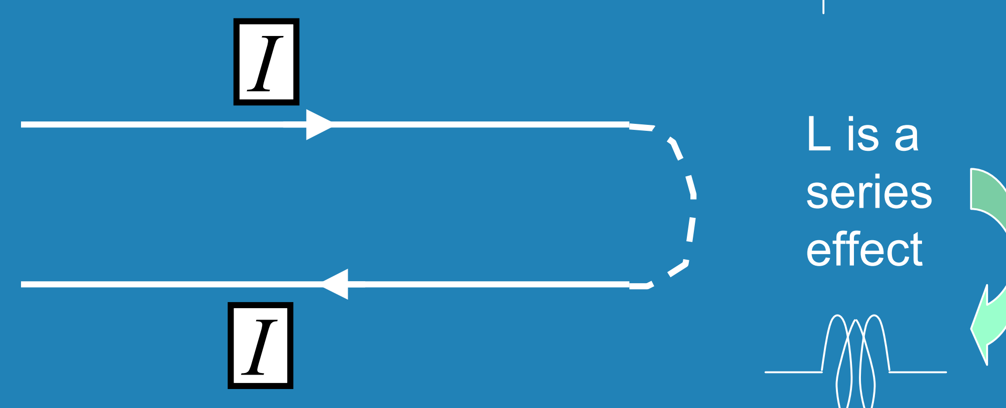
But, calculations use ***V*** and ***I*** for predicting effects

Transmission Line Model

Cables have both ***L*** and ***C***:

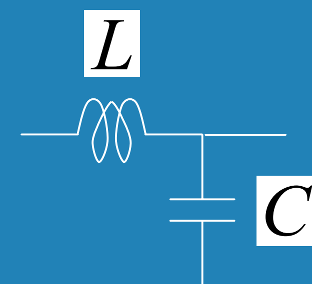


2 wire example:



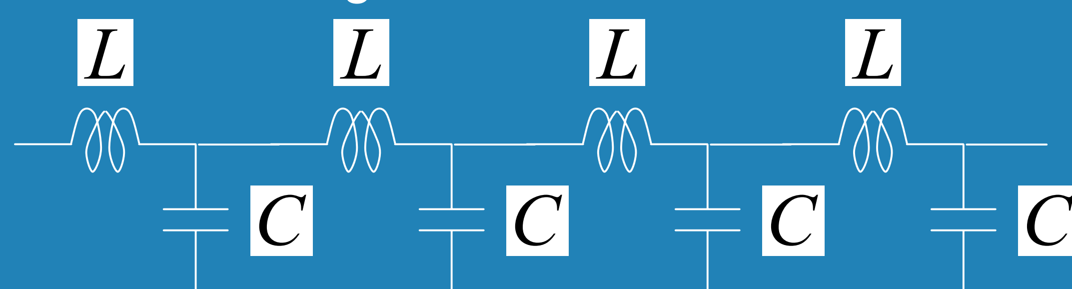
Transmission Line Model

Model of SHORT SECTION:



L and ***C*** are distributed through the length of the cable

Model the full length as:



….etc.

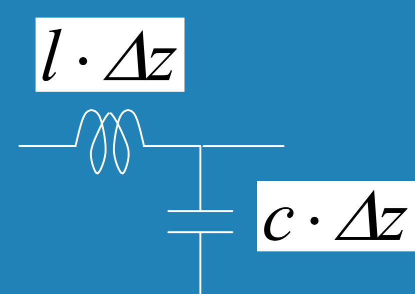
Do Experiment 1

Transmission Line Model

Does ***L*** **-*C*** combination behave like a cable?
How would you know?

Time Delay ~ same as cable delay

Each,



, represents a length of cable

l = inductance/length

c = capacitance/length

Do Problem 1

Transmission Line Model

When is model of ***L*** - ***C*** combination valid?

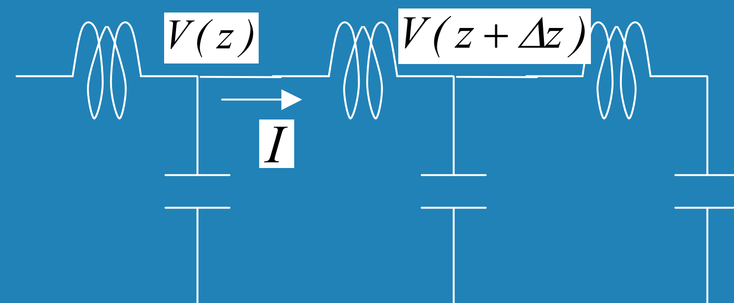
- need Δz small → $\Delta z << \lambda$

- chosen Δz is a compromise
- works well at 600 kHz but not 6 MHz

At 6 MHz, the ***L*** - ***C*** model is a low pass filter but coax-cable <u>is not</u>

Transmission Line Representation

As $\Delta z \Rightarrow 0$ limit



$$V(z+\Delta z) - V(z) = -L\frac{\partial I}{\partial t}$$

$L = l \cdot \Delta z$

$$-l \cdot \frac{\partial I}{\partial t} = \frac{\Delta V}{\Delta z} = \frac{\partial V}{\partial t}$$

Transmission Line Representation

Similarly, $\frac{\partial I}{\partial z} = -c \cdot \frac{\partial V}{\partial t}$

$$\frac{\partial^2 V}{\partial z^2} = \frac{\partial}{\partial z}\left(-l \cdot \frac{\partial I}{\partial t}\right) = -l \cdot \frac{\partial}{\partial t}\left(\frac{\partial I}{\partial z}\right) = lc \frac{\partial^2 V}{\partial t^2}$$

Obtain the following PDE: $\frac{\partial^2 V}{\partial z^2} = lc \frac{\partial^2 V}{\partial t^2}$

Solutions are: $f\left(t \pm \frac{z}{u}\right)$

These are functions that move with velocity ***u***

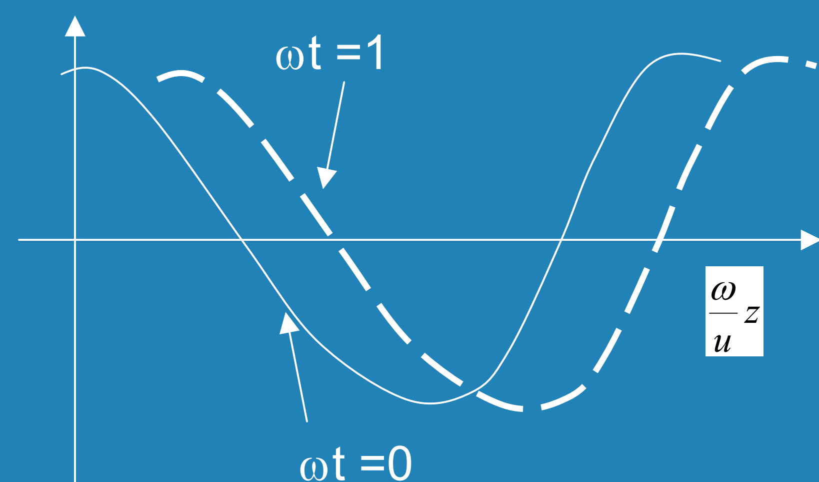
Transmission Line Representation

Functions that move with velocity ***u***

Example: $$\cos(\omega t \pm \frac{\omega}{u} z)$$

At t=0, $$\cos(-\frac{\omega}{u} z)$$ Wave moving to the right

At ωt =1 $$\cos(1 - \frac{\omega}{u} z)$$



Transmission Line

Do Problem 2

Do Problem 3