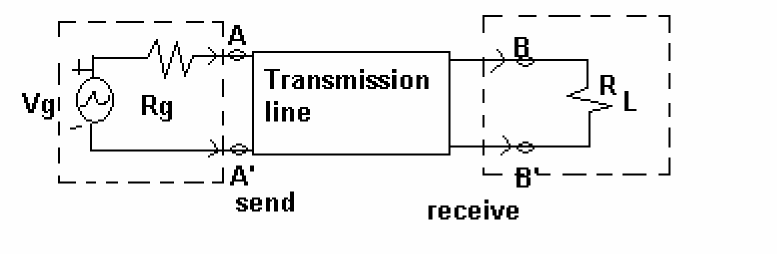
ECE 6130: LECTURE 1
REVIEW TRANSMISSION LINES

Text Section 2.1, Handout

Portfolio:
1) Describe the lumped element transmission line model.
2) Describe how to calculate the lumped element values for known lines such as coaxial and microstripline (See Chapter 2 Problems 1,2)

"Transmission Line" -- Any structure or media which *guides* EM waves from one location to another.

Two-port circuit diagram:



<u>Effect of Transmission line (function of frequency and speed of wave):</u>

$V_{AA'} = V_g(t) = V_o\cos(\omega t)$ volts

$V_{BB'} = V_{AA'}(t + t_{delay}) = V_o\cos(\omega(t + \text{length/speed}))$ volts
Speed = vo = 2.996e8 m/s

Example 1: f = 60 Hz, length = 1 meter, $\omega * t_{delay}$ = .0000012, $V_{BB'} = V_{AA'}$
Example 2: f = 1GHz, length = 1meter, $\omega * t_{delay}$ = 20.94 radians ! 6.67 cycles, $V_{BB'}$ = -0.49*$V_{AA'}$
Example 3: f=10 GHz, length = 1cm, $\omega * t_{delay}$ = 2.094 radians, $V_{BB'}$ =-.49*$V_{AA'}$

<u>Reflections:</u>
With 6.67 cycles, there has been a lot of time for bounces (reflections) to get back to source.

- Reflections add (you think your computer line = 0.0, but it actually = .5, which is enough to give a digital "1")
- Reflections subtract (you think your power is 1 W, but it is actually .5 W)

<u>Power Loss</u>

- Reflections through lossy material
- Multiple bounces through semi-lossy material

<u>Dispersive effects:</u>

- Many materials have different properties at different frequencies. All water-based materials, many semi-conductors, etc.

<u>Propagation Modes</u>

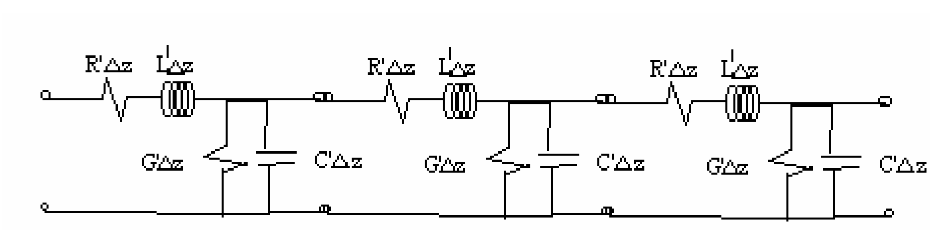
- TEM : Transverse Electromagnetic (** we are going to study these)
  Transverse = perpendicular
  E and **H** fields are both entirely perpendicular to the direction of propagation.
  Made up of two parallel conducting surfaces:
  Coaxial Line: See transparency Figure 2-5

- Higher - order transmission lines:
  E and **H** fields have at least one significant component in direction of propagation. Combination of TE and TM.

<u>Lumped –Element Model:</u>

TEM transmission lines (remember, no fields in the direction of propagation) can be represented by a lumped element model …

- Parallel-wire equivalent
- Represents motion of fields down the transmission line
- Transverse field effects (all fields ARE transverse in TEM) are modeled by equivalent circuit elements … RLC
- Accuracy of method depends on:
  - True TEM nature (non-transverse fields not properly modeled)
  - Correct calculation of circuit parameters (RLC) of line (done analytically, as we will do in a minute)



"Lumped" Elements:

R' : Combined resistance of both conductors / unit length (ohm/meter)
L': Combined inductance of both conductors / unit length (H/m)

G' : Combined conductance of both conductors / unit length (S/m = 1/ (ohm-meter))
C': Combined capacitance of both conductors / unit length (F/m)

How do you get them? From derivations See in a minute→ Tabulated for standard transmission lines

What effects do we see?
R' : Waves move down the transmission lines, but if the material has a resistance (anything except a perfect conductor), R' .ne. 0. Resistance would be continuous, rather than discrete as shown … it is exact in the limit as $\Delta z \rightarrow 0$. Thus a "lumped" element, is generally an approximation.

L': Inductance represents magnetic flux generated by the current on the transmission line. Again, it would be continuous, but is represented by a small lumped element.

G': Conductance (1/R) . This represents coupling currents between the line. If the internal material has some conductivity, it can draw current from one line to the other.

C': Capacitance between the lines. Charges induced on the lines produce a voltage . Capacitance is charge/voltage.

For all TEM lines (properties are of insulating material):

$L'C' = \mu \varepsilon$
$G'/C' = \sigma / \varepsilon$

<u>Characteristic Impedance</u>
Zo = Vo+ / Io+ = Vo- / Io- = sqrt((R+jωL)/(G+jωC))