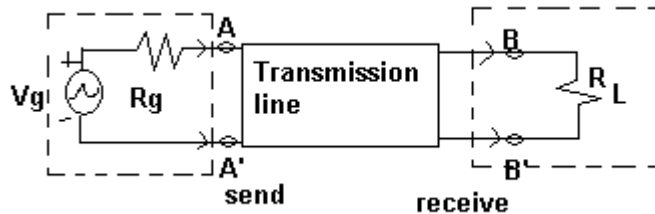


## ECE 3300: TRANSMISSION LINES

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

Two-port circuit diagram:



### **THIS SECTION IS NOT IN YOUR TEXT, but it is important:** **Effect of Transmission line (function of frequency and speed of wave):**

“Transmission line effects” occur when the delay down the transmission line(s) in your device are ‘significant’ and change the way your device operates. Other electrical engineering applications you are familiar with do not need to consider transmission line effects, because they are so short (in meters) compared to the electrical wavelength (also in meters). This is because the frequencies you have considered in your other classes are relatively low (kHz and low MHz), and your devices have been small enough to fit on a circuit board or protoboard. If you consider very large devices (such as overland transmission lines) at these low frequencies, you have to consider transmission line effects, because the electrical delays on the lines are significant. If you use higher frequencies, the wavelength becomes smaller. (Remember: wavelength =  $c / f$  = speed of light / frequency). When the wavelength is smaller, smaller devices start to exhibit transmission line effects. This section of the lecture notes helps you decide when you should / should not include transmission line effects in your calculations.

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

$V_{BB'} = V_{AA'}(t + t_{\text{delay}}) = V_o \cos(\omega(t + \text{length}/\text{speed}))$  volts  
Speed =  $v_p = 2.996e8$  m/s \* 2/3 (typically)

Example 1:  $f = 60$  Hz, length = 1 meter,  $\omega * t_{\text{delay}} = .0000012$ ,  $V_{BB'} = V_{AA'}$

Example 2:  $f = 1$ GHz, length = 1meter,  $\omega * t_{\text{delay}} = 20.94$  radians ! 6.67 cycles,  $V_{BB'} = -0.49 * V_{AA'}$

Example 3:  $f = 10$  GHz, length = 1cm,  $\omega * t_{\text{delay}} = 2.094$  radians,  $V_{BB'} = -.49 * V_{AA'}$

### **What sorts of Transmission Line Effects do we see?**

#### **Reflections:**

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)

### **Power Loss**

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

### **Dispersive effects:**

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

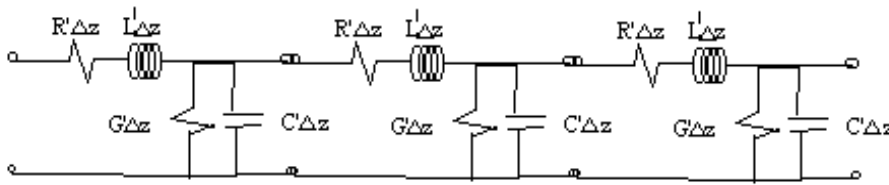
### **Propagation Modes**

- 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  
We'll study these in ECE315.

### **Lumped –Element Model:**

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 (later chapters) → Tabulated for standard transmission lines

Examples: Table 2.1

**What effects do we see?**

**R' :** Waves move down the transmission lines, but if the material has a resistance (anything except a perfect conductor),  $R' \neq 0$ . 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):**

$$L'C' = \mu \epsilon$$

$$G'/C' = \sigma / \epsilon$$