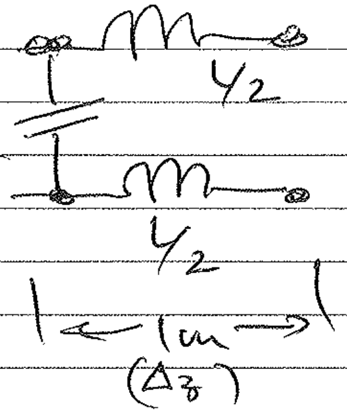
ENEL 434 Electronics II

Lecture 8

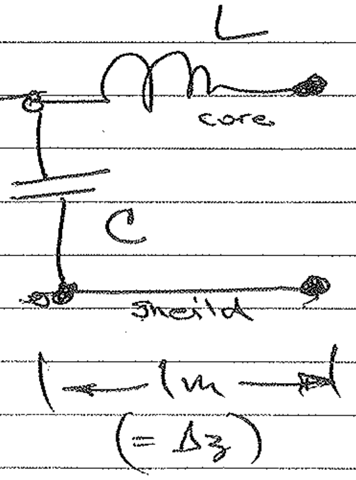
Tx line.

All tx lines can be modeled as a series of lumped components.

Balanced tx line



Coaxial or unbalanced tx line



For both

$$v_p = \frac{1}{\sqrt{LC}} \quad m/sec$$

$$Z_0 = \sqrt{\frac{L}{C}} \quad \text{in } \Omega$$

① $$L \frac{di}{dt} \cdot \Delta z = -\left(\frac{dv}{dz}\right) \Delta z$$

② $$C \frac{dv}{dt} \cdot \Delta z = -\left(\frac{di}{dz}\right) \Delta z$$

$\therefore$ ③ $$\frac{d^2 v}{dz^2} = LC \frac{d^2 v}{dt^2}$$

TABLE 14–1 Transmission-Line (Circuit) Characteristics (Refer to Figure 14–2 for dimensions.)

	$Z_0(\Omega)$	L (H/m)	C (F/m)
Twin lead	$\frac{120}{\sqrt{\epsilon_r}} \ln 2s/d$	$\frac{\mu}{\pi} \ln 2s/d$	$\frac{\pi\epsilon}{\ln 2s/d}$
Coaxial	$\frac{60}{\sqrt{\epsilon_r}} \ln D/d$	$\frac{\mu}{2\pi} \ln D/d$	$\frac{2\pi\epsilon}{\ln D/d}$
Microstrip (after H. A. Wheeler)	$Z_0 = 377h/\{\sqrt{\epsilon_r}W[1 + 1.74(\epsilon_r)^{-0.07}(W/h)^{-0.836}]\}$		

The ϵ_r for typical materials used in transmission lines are (at 10 GHz): polystyrene 2.5, polyethylene 2.3, and Teflon 2.1.

NB

$\epsilon = \epsilon_r \epsilon_0 \qquad \epsilon_0 = 8.85 \times 10^{-12}$ F/m.

$\mu = \mu_r \mu_0 \qquad \mu_0 = 4 \cdot \pi \times 10^{-7}$ H/m

EXAMPLE 14–1

A very low-loss coaxial transmission line has 30 pF/ft of distributed capacitance and 75 nH/ft of inductance. Determine the following:

1. The capacitance of a 3-ft length of this line used as an oscilloscope probe
2. Z_0
3. The velocity of propagation for a voltage and current transient (velocity relative to a TEM wave in free space)
4. The time required for an input transient to reach the oscilloscope (see part 1)
5. The ratio of shield diameter to center conductor diameter of the coax

Solution:

1. 30 pF/ft × 3 ft = **90 pF.** This can greatly decrease the high-frequency response of a circuit under test.
2. $Z_0 = \sqrt{L/C} = \sqrt{75 \times 10^{-9}/(30 \times 10^{-12})} = \mathbf{50\ \Omega.}$
3. $v_p = 1/\sqrt{LC} = 1/\sqrt{75 \times 30 \times 10^{-21}} = \mathbf{666.7 \times 10^6}$ **ft/s.** $v_p = (666.7 \times 10^6$ ft/s) (1 mi/5280 ft) = 126,263 mi/s, so that v_p/c = 126,263/186,000 = **0.679**—a little more than two-thirds the speed of light.
4. $d = v_p t$. $t = 3$ ft/(666.7×10^6 ft/s) = **4.5 ns.**
5. Table 14–1 gives $Z_0 = (60/\sqrt{\epsilon_r})\ln D/d$. From Equation 14–2, $\sqrt{\epsilon_r} = c/v_p = 1/0.679$, and from part 2, $Z_0 = 50\ \Omega$. Therefore, $50 \times 1.473/60 = 1.228 = \ln D/d$. By the definition of logarithms, $D/d = e^{1.228} = \mathbf{3.41.}$