Fields and Waves

Lesson 4.5

LOSSY TRANSMISSION LINES

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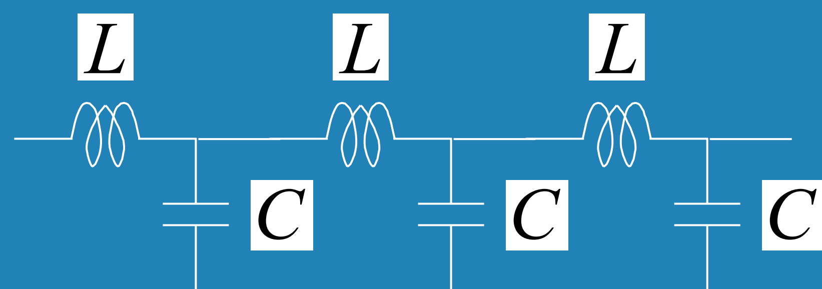
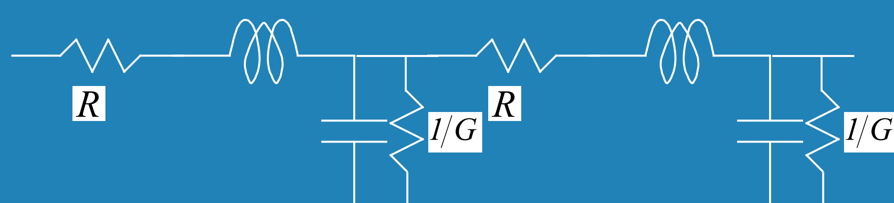
Lossless/Lossy Models of TL

Lossless Model of TL:



Lossy Model of TL:



Loss effects due to Resistances:

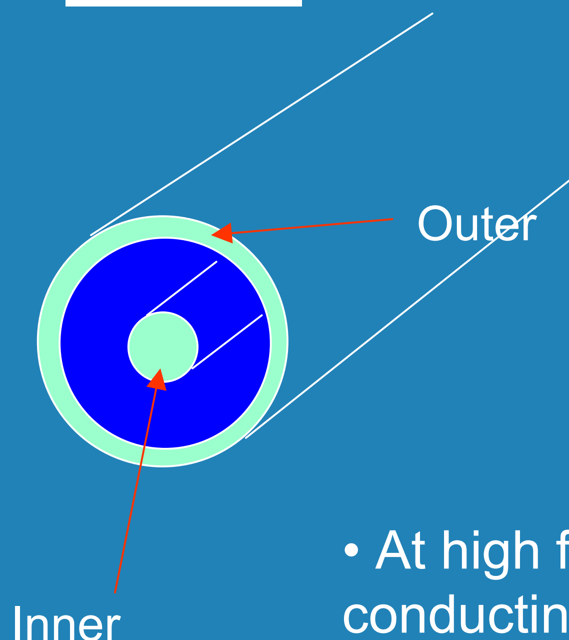
R - resistance of conductors

G - conductivity of insulators

- both are ideally small

Estimation of R

$R = \frac{l}{\sigma \cdot A}$, if constant cross-section



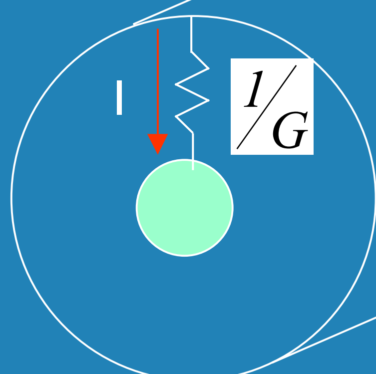
On a per meter basis,

$$r = \left.\frac{1}{\sigma \cdot A}\right|_{inner} + \left.\frac{1}{\sigma \cdot A}\right|_{outer}$$

because inner and outer conductors are in series

- At high frequencies, not all the copper is used for conducting (see Lesson 3.1)
- Current only flows in outer portion due to skin depth effects

Estimation of G



The 1/G component represents radial current flow, due to small σ of insulator

- the cross-sectional area is not constant

$$\therefore G = \frac{1}{R} \neq \frac{\sigma \cdot A}{l}$$

Estimation of G:

$$G = \frac{1}{R} = \frac{I}{V} = \frac{\oint \vec{j} \bullet d\vec{s}}{V_{ab}}$$

$$= \frac{\sigma}{\varepsilon} \cdot \frac{\oint \vec{D} \cdot d\vec{s}}{V_{ab}} = \frac{\sigma}{\varepsilon} \cdot \frac{Q}{V_{ab}} = \frac{\sigma}{\varepsilon} \cdot C$$

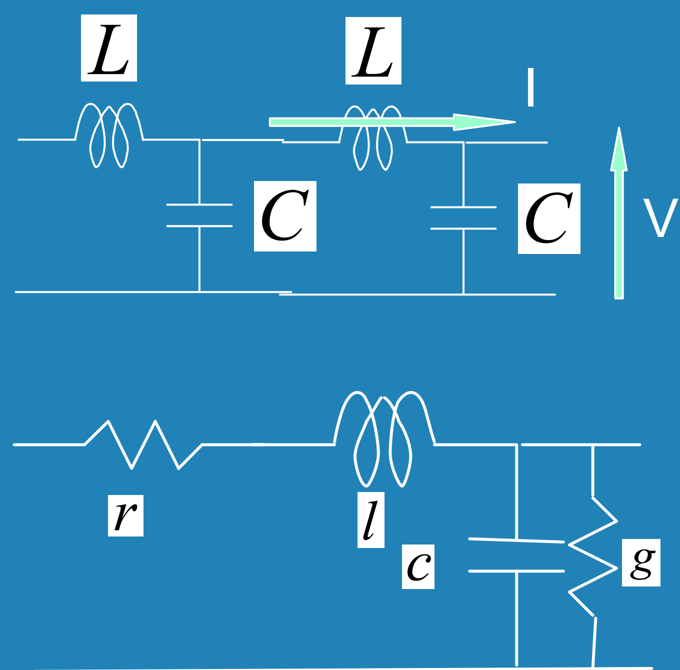
From Electrostatics,

$$\vec{j} = \sigma \cdot \vec{E} = \frac{\sigma}{\varepsilon} \cdot \vec{D}$$

Also, $g = \frac{G}{l} = \frac{\sigma}{\varepsilon} \cdot c$

Do Problem 1a &1b

Effects on Z_c - Characteristic Impedance



For Lossless system,
R_c represents $= \frac{\hat{V}}{\hat{I}}$

$$R_c = \sqrt{\frac{l}{c}}$$

Replace ***j.ω.l*** with ***r + j.ω.l***

Replace ***j.ω.c*** with ***g + j.ω.c***

Characteristic Impedance

$$Z_c = \sqrt{\frac{r + j \cdot \omega \cdot l}{g + j \cdot \omega \cdot c}}$$

Attenuation Factor

For lossless systems: $\beta = \omega \cdot \sqrt{l \cdot c}$

For lossy systems:

$$\gamma = \alpha + j \cdot \beta = \sqrt{(r + j \cdot \omega \cdot l)(g + j \cdot \omega \cdot c)}$$

The phasors have the factor:

$$e^{-\gamma \cdot z} = e^{-\alpha \cdot z} \cdot e^{-j \cdot \beta \cdot z}$$

Attenuation/loss factor due to resistance