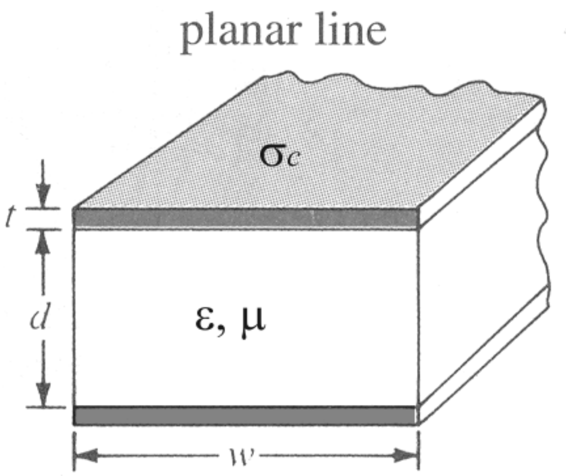
We have made a parallel plate transmission line by cutting a 0.75” wide strip from a 0.25” thick plexiglass board from Ace Hardware covered with lead tape (24 μm thick). If the transmission line is operated at 3 GHz at room temperature, determine: a) the effective conductivity and complex permittivity of the plexiglass, and b) skin depth & distributed parameters *R*, *L*, *G*, & *C* of the transmission line. [Hint: Appendices E, F, & G.]



w = 0.75” = 0.75(2.54) = 1.905 cm

d = 0.25” = 0.25(2.54) = 0.635 cm

t = 24 μm

a) From Appendix G, $\varepsilon_r = 2.60$ and $\tan\delta = 0.0057$ at 3 GHz for plexiglass.

Per notes, $\varepsilon' = \varepsilon_r\, \varepsilon_0 = 2.60\,(8.8541878\times10^{-12}$ F/m), and $\varepsilon'' = \varepsilon' \tan\delta =$ $2.3021\times10^{-11}\,(0.0057)$. Putting these together, yields $\varepsilon = \varepsilon_c = \varepsilon' - j\varepsilon''$

$\Rightarrow$ **$\varepsilon = \varepsilon_c = 2.30209 \times 10^{-11} - j1.31219 \times 10^{-13}$ F/m**.

Per notes, $\varepsilon'' = \sigma / \omega$. So, the effective conductivity is $\sigma = \omega\, \varepsilon''$.

$\sigma = 2\pi\,(3\times10^{9})\; 1.31219\times10^{-13}$ $\Rightarrow$ **σ = 0.0024734 S/m = 2.4734 mS/m**.

b) From Appendix F, $\sigma = 4.56 \times 10^{6}$ S/m for lead. Per EE 381 text, lead is diamagnetic, i.e., $\mu = 0.9999831\,\mu_0 \cong \mu_0$.

Per (1.60), $\delta_s = \sqrt{\dfrac{2}{\omega\mu\sigma}} = \sqrt{\dfrac{2}{2\pi(3\bullet10^{9})4\pi\bullet10^{-7}(4.56\bullet10^{6})}}$

$\Rightarrow$ **$\delta_s = 4.30309 \times 10^{-6}$ m = 4.30309 μm**.

Note: The lead tape thickness t = 24 mm >> δ_s.

Plexiglass is a hydrocarbon-based plastic $\Rightarrow$ non-magnetic $\mu = \mu_0$.

Using equations from Table 2.1,

$$L = \frac{\mu d}{w} = \frac{4\pi \times 10^{-7}(1.905)}{0.635} \quad \Rightarrow \quad \underline{\boldsymbol{L = 4.1888 \times 10^{-7}\ \text{H/m} = 418.88\ \text{nH/m}}}$$

$$C = \frac{\varepsilon' w}{d} = \frac{(2.6)8.8541878 \times 10^{-12}(0.635)}{1.905}$$

$$\Rightarrow \underline{\boldsymbol{C = 6.9063 \times 10^{-11}\ \text{F/m} = 69.063\ \text{pF/m}}}$$

$$R = \frac{2R_s}{w} = \frac{2}{\sigma\delta_s w} = \frac{2}{4.56 \times 10^{6}(4.30309 \times 10^{-6})1.905 \times 10^{-2}} \quad \Rightarrow \quad \underline{\boldsymbol{R = 5.35044\ \Omega/\text{m}}}$$

[Per page 52 of the text, the surface resistance $R_s = 1/\sigma\delta_s$.]

$$G = \frac{\omega\varepsilon'' w}{d} = \frac{2\pi(3 \times 10^{9})1.31219 \times 10^{-13}(1.905)}{0.635}$$

$$\Rightarrow \underline{\boldsymbol{G = 7.4203 \times 10^{-3}\ \text{S/m} = 7.4203\ \text{mS/m}}}$$