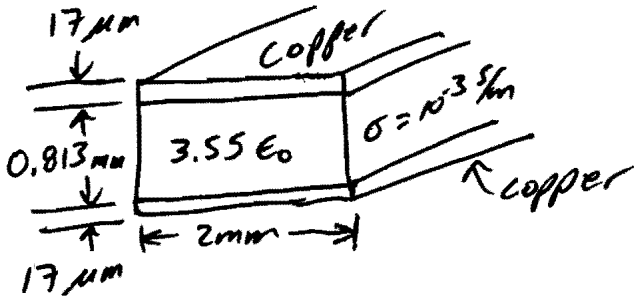
A planar line of width 2 mm is made on Rogers Corporation RO4003C substrate which has a non-magnetic dielectric substrate with a relative permittivity of 3.55, loss tangent of 0.0021 ($\sigma = 10^{-3}$ S/m), thickness of 0.813 mm, and 0.5 oz copper cladding (17 μm thick). When operated at 2.4 GHz, find the per-unit-length parameters R, L, C, and G. Also, calculate the skin depth δ before finding R.



From Appendix B,

$\sigma_c = \sigma_{Cu} = 5.8 \times 10^7$ S/m

$\mu_c = \mu_{Cu} \simeq \mu_0 = 4\pi \times 10^{-7}$ S/m

Table 11.1 Skin depth for copper

$$\delta = \frac{1}{\sqrt{\pi f \mu_c \sigma_c}} = \frac{1}{\sqrt{\pi (2.4\times10^9) 4\pi\times10^{-7} (5.8\times10^7)}}$$

$$\delta = 1.349\ \mu m \quad << t = 17\ \mu m$$

$$R = \frac{2}{w \delta \sigma_c} = \frac{2}{2\times10^{-3} (1.349\times10^{-6}) 5.8\times10^7}$$

$$R = 12.7812\ \Omega/m$$

$$L = \frac{\mu d}{w} = \frac{\mu_0 d}{w} = \frac{4\pi\times10^{-7} (0.813\times10^{-3})}{2\times10^{-3}}$$

$$L = 5.1082\times10^{-7}\ H/m = 510.82\ nH/m$$

$$G = \frac{\sigma w}{d} = \frac{10^{-3} (2\times10^{-3})}{0.813\times10^{-3}} \Rightarrow G = 2.460\ mS/m$$

$$C = \frac{\epsilon w}{d} = \frac{3.55 (8.8541878\times10^{-12}) (2\times10^{-3})}{0.813\times10^{-3}}$$

$$C = 7.7324\times10^{-11}\ F/m = 77.324\ pF/m$$