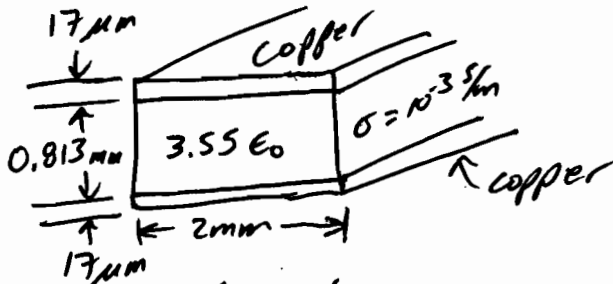


A planar line of width 2 mm is made on Rogers Corporation RO4003C substrate which has a dielectric substrate with a relative permittivity of 3.55, loss tangent of 0.0021 ( $\sigma = 10^{-3}$  S/m), thickness of 0.813 mm, and 0.5 oz copper cladding (17  $\mu\text{m}$  thick). When operated at 2.4 GHz, find the per-unit-length parameters  $R$ ,  $L$ ,  $C$ , and  $G$ . [Hint: Consult Appendix B for copper material properties.]



From Appendix B,

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

$$\mu_c = \mu_{cu} \approx \mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

Table 11.1

Skin depth  
for copper

$$\delta = \frac{1}{\sqrt{\pi f \mu_c \sigma_c}} = \frac{1}{\sqrt{\pi (2.4 \times 10^9) 4\pi \times 10^{-7} (5.8 \times 10^7)}}$$

$$\delta = 1.349 \mu\text{m} \ll t = 17 \mu\text{m}$$

$$R = \frac{2}{W \delta \sigma_c} = \frac{2}{2 \times 10^{-3} (1.349 \times 10^{-6}) 5.8 \times 10^7}$$

$$\underline{R = 12.7812 \ \Omega/\text{m}}$$

$$L = \frac{\mu d}{W} = \frac{\mu_0 d}{W} = \frac{4\pi \times 10^{-7} (0.813 \times 10^{-3})}{2 \times 10^{-3}}$$

$$\underline{L = 5.1082 \times 10^{-7} \text{ H/m} = 510.82 \text{ nH/m}}$$

$$G = \frac{\sigma W}{d} = \frac{10^{-3} (2 \times 10^{-3})}{0.813 \times 10^{-3}} \Rightarrow \underline{G = 2.460 \text{ mS/m}}$$

$$C = \frac{\epsilon W}{d} = \frac{3.55 (8.8541878 \times 10^{-12}) (2 \times 10^{-3})}{0.813 \times 10^{-3}}$$

$$\underline{C = 7.7324 \times 10^{-11} \text{ F/m} = 77.324 \text{ pF/m}}$$