EE 481/581 Microwave Engineering
Quiz #2 (Fall 2024)

Name Key A

Instructions: Open book & notes. Place answers in indicated spaces and show all work for credit.

A coaxial transmission line is to be fashioned for operation at 2.4 GHz using a brass alloy (ε_0, μ_0, $\sigma_{brass} = 2.4 \times 10^7$ S/m) for the conductors and a plastic for the insulator ($\varepsilon_r = 2.4$, μ_0, $\tan\delta = 2.4 \times 10^{-3}$). If the inner and outer conductors have diameters of 3 mm and 9 mm respectively, find the complex permittivity & effective conductivity of the insulator, skin depth of the conductors, and distributed parameters R, L, G, & C of the transmission line. The outer conductor is 0.5 mm thick.

Notes: $\epsilon' = \epsilon_r \epsilon_0 = 2.4(8.854187 \times 10^{-12}) = 2.125 \times 10^{-11}$ F/m

$\epsilon'' = \epsilon' \tan\delta = 2.125 \times 10^{-11}(2.4 \times 10^{-3}) = 5.10001 \times 10^{-14}$ F/m

$\sigma_{eff} = \epsilon'' \omega = 5.1 \times 10^{-14}(2\pi)\, 2.4 \times 10^9 = 7.69064 \times 10^{-4}$ S/m

Table 2.1

$\delta_s = \sqrt{\frac{2}{\omega \mu_0 \sigma_{brass}}} = \sqrt{\frac{2}{2\pi(2.4\times10^9)(4\pi\times10^{-7})\,2.4\times10^7}} = 2.09705 \times 10^{-6}$ m

$R = \frac{1}{2\pi\sigma\delta_s}\left(\frac{1}{a} + \frac{1}{b}\right) = \frac{1}{2\pi(2.4\times10^7)\,2.097\times10^{-6}}\left(\frac{1}{1.5\times10^{-3}} + \frac{1}{4.5\times10^{-3}}\right)$

$R = 2.8109$ Ω/m

$L = \frac{\mu_0}{2\pi}\ln(b/a) = \frac{4\pi\times10^{-7}}{2\pi}\ln\left(\frac{4.5}{1.5}\right) = 2.19722 \times 10^{-7}$ H/m

$G = \frac{2\pi\omega\epsilon''}{\ln(b/a)} = \frac{2\pi(2.4\times10^9)2\pi(5.1\times10^{-14})}{\ln(4.5/1.5)} = 0.0043984$ S/m

$C = \frac{2\pi\epsilon'}{\ln(b/a)} = \frac{2\pi(2.125\times10^{-11})}{\ln(4.5/1.5)} = 1.21533 \times 10^{-10}$ F/m

$\varepsilon_c =$ $2.125 \times 10^{-11} - j\,5.1 \times 10^{-14}$ F/m

$\sigma_{ins} =$ 7.6906×10^{-4} S/m

$\delta_s =$ 2.09705 μm

$R =$ 2.8109 Ω/m

$L =$ 219.722 nH/m

$G =$ 4.3984 mS/m

$C =$ 121.533 pF/m

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Name Key B

Instructions: Open book & notes. Place answers in indicated spaces and show all work for credit.

A coaxial transmission line is to be fashioned for operation at 2.6 GHz using a brass alloy (ε_0, μ_0, $\sigma_{brass} = 2.6 \times 10^7$ S/m) for the conductors and a plastic for the insulator ($\varepsilon_r = 2.6$, μ_0, $\tan\delta = 2.6 \times 10^{-3}$). If the inner and outer conductors have diameters of 2 mm and 8 mm respectively, find the complex permittivity & effective conductivity of the insulator, skin depth of the conductors, and distributed parameters R, L, G, & C of the transmission line. The outer conductor is 0.5 mm thick.

Notes: $\epsilon' = \epsilon_r \epsilon_0 = 2.6(8.854187878\times10^{-12}) = 2.30209\times10^{-11}$ F/m

$\epsilon'' = \epsilon' \tan\delta = 2.302\times10^{-11}(2.6\times10^{-3}) = 5.98543\times10^{-14}$ F/m

$\sigma_{eff} = \epsilon'' \omega = 5.985\times10^{-14}(2\pi)2.6\times10^{9} = 9.77797\times10^{-4}$ S/m

Table 2.1: $\delta_s = \sqrt{\frac{2}{\omega\mu\sigma_{brass}}} = \sqrt{\frac{2}{2\pi(2.6\times10^9)4\pi\times10^{-7}(2.6\times10^7)}} = 1.93574\times10^{-6}$ m

$R = \frac{1}{2\pi a \delta_s}\left(\frac{1}{a}+\frac{1}{b}\right) = \frac{1}{2\pi(2.6\times10^7)1.936\times10^{-6}}\left(\frac{1}{1\times10^{-3}}+\frac{1}{4\times10^{-3}}\right)$

$R = 3.95285\ \Omega/m$

$L = \frac{\mu_0}{2\pi}\ln(b/a) = \frac{4\pi\times10^{-7}}{2\pi}\ln(4/1) = 2.77259\times10^{-7}$ H/m

$G = \frac{2\pi\omega\epsilon''}{\ln(b/a)} = \frac{2\pi(2\pi)2.6\times10^9(5.985\times10^{-14})}{\ln(4/1)} = 4.43173\times10^{-3}$ S/m

$C = \frac{2\pi\epsilon'}{\ln(b/a)} = \frac{2\pi(2.302\times10^{-11})}{\ln(4/1)} = 1.04339\times10^{-10}$ F/m

$\varepsilon_c = 2.3021\times10^{-11} - j\,5.9854\times10^{-14}$ F/m $\sigma_{ins} = 9.778\times10^{-4}$ S/m

$\delta_s = 1.9357\ \mu m$ $R = 3.95285\ \Omega/m$ $L = 277.259$ nH/m

$G = 4.4317$ mS/m $C = 104.339$ pF/m