2.1 A two-wire copper transmission line is embedded in a dielectric material with $\varepsilon_r = 2.6$ and $\sigma = 2 \times 10^{-6}$ S/m. Its wires are separated by 3 cm and their radii are 1 mm each.

(a) Calculate the line parameters R', L', G', and C' at 2 GHz.

(b) Compare your results with those based on CD Module 2.1. Include a printout of the screen display.

Solution:

(a) Given:

$$f = 2 \times 10^9 \text{ Hz},$$
$$d = 2 \times 10^{-3} \text{ m},$$
$$D = 3 \times 10^{-2} \text{ m},$$
$$\sigma_c = 5.8 \times 10^7 \text{ S/m (copper)},$$
$$\varepsilon_r = 2.6,$$
$$\sigma = 2 \times 10^{-6} \text{ S/m},$$
$$\mu = \mu_c = \mu_0.$$

From Table 2-1:

$$\begin{aligned} R_s &= \sqrt{\pi f \mu_c / \sigma_c} \\ &= [\pi \times 2 \times 10^9 \times 4\pi \times 10^{-7} / 5.8 \times 10^7]^{1/2} \\ &= 1.17 \times 10^{-2} \ \Omega, \\ R' &= \frac{2R_s}{\pi d} = \frac{2 \times 1.17 \times 10^{-2}}{2\pi \times 10^{-3}} = 3.71 \ \Omega/\text{m}, \\ L' &= \frac{\mu}{\pi} \ln \left[(D/d) + \sqrt{(D/d)^2 - 1} \right] \\ &= 1.36 \times 10^{-6} \text{ H/m}, \\ G' &= \frac{\pi \sigma}{\ln[(D/d) + \sqrt{(D/d)^2 - 1}]} \\ &= 1.85 \times 10^{-6} \text{ S/m}, \\ C' &= \frac{G' \varepsilon}{\sigma} \\ &= \frac{1.85 \times 10^{-6} \times 8.85 \times 10^{-12} \times 2.6}{2 \times 10^{-6}} \end{aligned}$$

$= 2.13 \times 10^{-11}$ F/m.

(b) Solution via Module 2.1: