2.2 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 Module 2.1. Include a printout of the screen display.

Solution:

(a) Given:

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

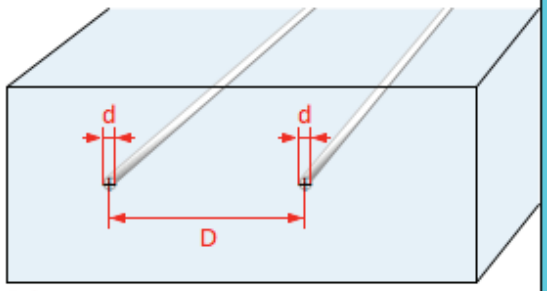
From Table 2-1:

$$\begin{aligned} R_s &= \sqrt{\pi f \mu_c / \sigma_c} \\ &= [\pi \times 2 \times 10^9 \times 4\pi \times 10^{-7} / 5.8 \times 10^7]^{1/2} \\ &= 1.17 \times 10^{-2} \ \Omega, \\ R' &= \frac{2R_s}{\pi d} = \frac{2 \times 1.17 \times 10^{-2}}{2\pi \times 10^{-3}} = 3.71 \ \Omega/\text{m}, \\ L' &= \frac{\mu}{\pi} \ln \left[(D/d) + \sqrt{(D/d)^2 - 1} \right] \\ &= 1.36 \times 10^{-6} \text{ H/m}, \\ G' &= \frac{\pi \sigma}{\ln[(D/d) + \sqrt{(D/d)^2 - 1}]} \\ &= 1.85 \times 10^{-6} \text{ S/m}, \\ C' &= \frac{G' \varepsilon}{\sigma} \\ &= \frac{1.85 \times 10^{-6} \times 8.85 \times 10^{-12} \times 2.6}{2 \times 10^{-6}} \\ &= 2.13 \times 10^{-11} \text{ F/m}. \end{aligned}$$

(b) Solution via Module 2.1:

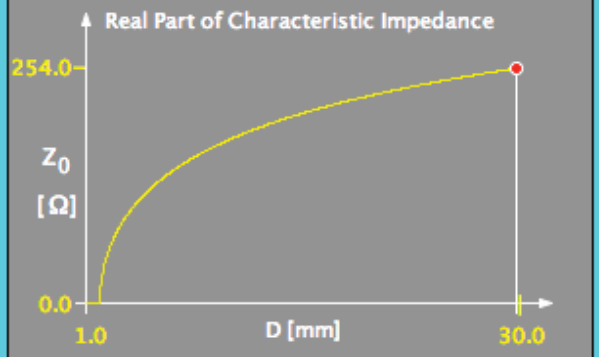
Module 2.1 Two-Wire Line

Select: Impedance vs. Distance D



Substrate
ε_r = 2.6
σ = 2.0E-6 [S/m]

Wires
σ_c = 5.8E7 [S/m]



Input

Wire Diameter d = 2.0 [mm]
Range

Centers distance D = 30.0 [mm]
Range

Frequency f = 2.0E9 [Hz]
Range

ε_r	σ [S/m]	σ_c [S/m]
2.6	2E-6	5.8E7

Update

Output

f = 2.0 [GHz]

Structure Data

d = 2.0 [mm] D / d = 15.0
D = 30.0 [mm]

Z_0	= 253.037142 - j 0.026617	[Ω]
C´	= 21.241303	[pF/m]
L´	= 1.360034	[μ H/m]
R´	= 3.713907	[Ω /m]
G´	= 2.0E-6	[S/m]
λ_0	= 0.15 [m]	in vacuum
λ	= 9.3026 [cm]	in guide
α	= 0.007572	[Np/m]
β	= 67.542213	[rad/m]