Ex. Check to see if the Belden 9085 twin-lead transmission line is distortionless and/or low loss at 100 MHz.

************* **From earlier example** **
Quantities that we looked up or were given:

$\varepsilon0 := 8.85419 \cdot 10^{-12}$ F/m $\qquad \mu0 := 4 \cdot \pi \cdot 10^{-7}$ H/m $\qquad f := 100 \cdot 10^{6}$ Hz

$a := 0.5 \cdot \left(0.644 \cdot 10^{-3}\right)$ $\qquad a = 3.22 \times 10^{-4}$ m $\qquad d := 7.4 \cdot 10^{-3}$ m

$\sigma\_ccs := 1 \cdot 10^{7}$ S/m $\qquad \varepsilon\_ccs := \varepsilon0$ $\qquad \mu\_ccs := \mu0$

$\sigma\_poly := 3 \cdot 10^{-5}$ S/m $\qquad \varepsilon\_poly := 2.26 \cdot \varepsilon0$ $\qquad \mu\_poly := \mu0$

$\sigma\_eff := 0.45 \cdot \sigma\_poly$ $\qquad \varepsilon\_eff := 0.55 \cdot \varepsilon0 + 0.45 \cdot \varepsilon\_poly$ $\qquad \mu\_eff := \mu0$

Use Table 11.1 equations to find per-unit-length parameters

$$\delta := \frac{1}{\sqrt{\pi \cdot f \cdot \mu\_ccs \cdot \sigma\_ccs}} \qquad \boxed{\delta = 1.592 \times 10^{-5}} \text{ m}$$

Check if δ << *a* to ensure equations are valid. $\qquad \frac{\delta}{a} = 0.049$

$$R := \frac{1}{\pi \cdot a \cdot \delta \cdot \sigma\_ccs} \qquad \boxed{R = 6.21118} \ \Omega/\text{m}$$

$$L := \frac{\mu\_eff}{\pi} \cdot \operatorname{acosh}\left(\frac{d}{2 \cdot a}\right) \qquad \boxed{L = 1.25311 \times 10^{-6}} \text{ H/m}$$

$$G := \frac{\pi \cdot \sigma\_eff}{\operatorname{acosh}\left(\frac{d}{2 \cdot a}\right)} \qquad \boxed{G = 1.3538 \times 10^{-5}} \text{ S/m}$$

$$C := \frac{\pi \cdot \varepsilon\_eff}{\operatorname{acosh}\left(\frac{d}{2 \cdot a}\right)} \qquad \boxed{C = 1.39135 \times 10^{-11}} \text{ F/m}$$

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Check if Belden 9085 is distortionless per (11.22)-

$\boxed{\frac{R}{L} = 4.9566 \times 10^{6}}$ $\qquad \boxed{\frac{G}{C} = 9.7301 \times 10^{5}}$

Since R/L is NOT equal to G/C, Belden 9085 has distortion.

Check if Belden 9085 is low loss at 100 MHz- $\omega := 2 \cdot \pi \cdot f$

Is R << ωL (i.e., R/ωL << 1)? $\frac{R}{\omega \cdot L} = 0.00789$ **Yes**

Is G << ωC (i.e., G/ωC << 1)? $\frac{G}{\omega \cdot C} = 0.00155$ **Yes**

Belden 9085 is low loss at 100 MHz!

How good are the low loss approximations?

Propagation constant

(11.11) $\gamma := \sqrt{(R + j \cdot \omega \cdot L) \cdot (G + j \cdot \omega \cdot C)}$ $\gamma = 0.01238 + 2.62359i$ 1/m

$\gamma LL := j \cdot \omega \cdot \sqrt{L \cdot C} \cdot \left[1 + \frac{1}{2 \cdot j \cdot \omega} \cdot \left(\frac{R}{L} + \frac{G}{C}\right)\right]$ $\gamma LL = 0.01238 + 2.62358i$ 1/m

Attenuation constant $\alpha := Re(\gamma)$ $\alpha = 0.01238$ Np/m

$\alpha LL := 0.5 \cdot \left(R \cdot \sqrt{\frac{C}{L}} + G \cdot \sqrt{\frac{L}{C}}\right)$ $\alpha LL = 0.01238$ Np/m

Phase constant $\beta := Im(\gamma)$ $\beta = 2.62359$ rad/m

$\beta LL := \omega \cdot \sqrt{L \cdot C}$ $\beta LL = 2.62358$ rad/m

Phase velocity (11.14) $u := \frac{\omega}{\beta}$ $u = 2.39488 \times 10^8$ m/s

$uLL := \frac{1}{\sqrt{L \cdot C}}$ $uLL = 2.39489 \times 10^8$ m/s

Characteristic Impedance (11.19) $Z0 := \sqrt{\frac{R + j \cdot \omega \cdot L}{G + j \cdot \omega \cdot C}}$ $Z0 = 300.11039 - 0.95134i$ Ω

$Z0LL := \sqrt{\frac{L}{C}} \cdot \left[1 + \frac{1}{2 \cdot j \cdot \omega} \cdot \left(\frac{R}{L} - \frac{G}{C}\right)\right]$ $Z0LL = 300.10741 - 0.95135i$ Ω

The low loss approximations are excellent for Belden 9085 at 100 MHz.