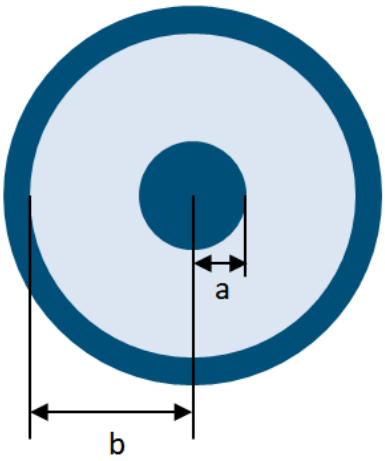
Coaxial Cable Transmission Line Design

Introduction

An electrical engineer is asked to design a coaxial transmission line with a characteristic impedence of 50 Ω and a phase velocity of at least 1.8×10^8 m s^{-1}

This application will calculate the outer radius of the line.

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> restart :
  with( Units[Simple] ) :
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Governing Equations

Capacitance and inductance per unit length for a coaxial cable transmission line

$$> c := \frac{2 \cdot \pi \cdot \epsilon_r \cdot \epsilon_0}{\ln\left(\frac{b}{a}\right)} :$$

$$> l := \frac{\mu_0}{8 \cdot \pi} + \frac{\mu_0}{2 \cdot \pi} \cdot \ln\left(\frac{b}{a}\right) :$$

Phase velocity

$$> v_p := \frac{1}{\sqrt{l \cdot c}}$$

(2.1)

$$v_p := \frac{\sqrt{2}}{2\sqrt{\frac{\left(\frac{\mu_0}{8\pi} + \frac{\mu_0 \ln\left(\frac{b}{a}\right)}{2\pi}\right)\pi \epsilon_r \epsilon_0}{\ln\left(\frac{b}{a}\right)}}} \tag{2.1}$$

Impedance of the coaxial cable tranmission line

> $Z_0 := \sqrt{\frac{l}{c}}$

$$Z_0 := \frac{\sqrt{2}\sqrt{\frac{\left(\frac{\mu_0}{8\pi} + \frac{\mu_0 \ln\left(\frac{b}{a}\right)}{2\pi}\right)\ln\left(\frac{b}{a}\right)}{\pi \epsilon_r \epsilon_0}}}{2} \tag{2.2}$$

Parameters

Permittivity and permeability of free space

> $\epsilon_0 := 8.854187817 \cdot 10^{-12}\ \mathrm{F\,m^{-1}}$:

$\mu_0 := 4 \cdot \pi \cdot 10^{-7}\ \mathrm{N\,A^{-2}}$:

Dieletric constant for Teflon

> $\epsilon_r := 2.1$:

Set the radius of the center conductor to be 22 gauge wire

> $Dia := 0.0253\ \mathrm{inch}$:

Solution

> $a := \frac{Dia}{2}$

$$1.26 \times 10^{-2}\ \mathrm{in} \tag{4.1}$$

> $eq := 50\,\mathrm{ohm} = Z_0$

$eq := 50$ (4.2)

$= 65420.07770\sqrt{2}$

$$\sqrt{\frac{\left(\frac{1}{20000000}\,\frac{N}{A^2}+\frac{\ln\left(\frac{79.05138340\,b}{in}\right)}{5000000}\,\frac{N}{A^2}\right)\ln\left(\frac{79.05138340\,b}{in}\right)}{\frac{F}{m}}}\,S$$

> $res := fsolve(eq, \{b = 2\cdot a\})$

$$\{b = 9.56 \times 10^{-4}\ m\} \tag{4.3}$$

Hence the phase velocity is

> $evalf(eval(v_p, res))$

$$1.87 \times 10^{8}\ \frac{m}{s} \tag{4.4}$$