2.9 A lossless microstrip line uses a 1 mm wide conducting strip over a 1 cm thick substrate with $\varepsilon_r = 2.5$. Determine the line parameters, ε_{eff}, Z_0, and β at 10 GHz. Compare your results with those obtained by using Module 2.3. Include a printout of the screen display.

Solution: Given

$$\begin{aligned} w &= 10^{-3} \text{ m}, \\ h &= 10^{-2} \text{ m}, \\ \varepsilon_r &= 2.5, \\ f &= 1 \times 10^{10} \text{ Hz}, \\ s &= \frac{w}{h} = 0.1. \end{aligned}$$

From Eq. (2.36),

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \left(\frac{\varepsilon_r - 1}{2}\right)\left(1 + \frac{10}{s}\right)^{-xy}$$

with

$$\begin{aligned} x &= 0.56\left[\frac{\varepsilon_r - 0.9}{\varepsilon_r + 3}\right]^{0.05} \\ &= 0.56\left[\frac{2.5 - 0.9}{2.5 + 3}\right]^{0.05} = 0.526, \\ y &= 1 + 0.02\ln\left(\frac{s^4 + 3.7 \times 10^{-4} s^2}{s^4 + 0.43}\right) \\ &\quad + 0.05\ln(1 + 1.7 \times 10^{-4} s^3) \\ &\approx 0.83, \end{aligned}$$

which leads to

$$\varepsilon_{eff} \approx 1.85.$$

By Eq. (2.39),

$$Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}} \ln\left\{\frac{6 + (2\pi - 6)e^{-t}}{s} + \sqrt{1 + \frac{4}{s^2}}\right\}$$

with

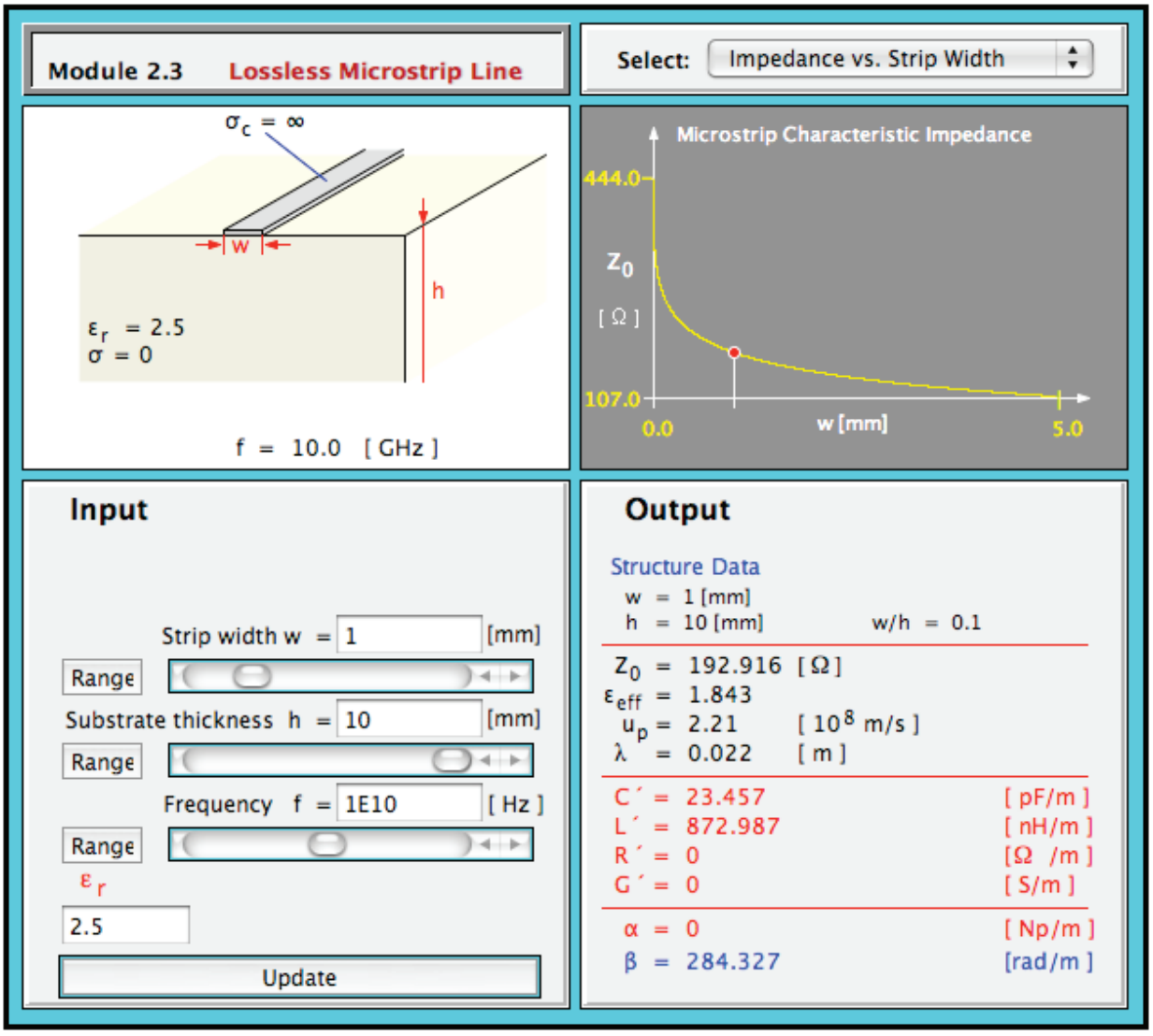
$$t = \left(\frac{30.67}{s}\right)^{0.75} = \left(\frac{30.67}{0.1}\right)^{0.75} = 73.29.$$

Hence,

$$Z_0 = 193.3 \ \Omega.$$

Also,

$$\beta = \frac{\omega}{c}\sqrt{\varepsilon_{eff}} = \frac{2\pi \times 10^{10}}{3 \times 10^8}\sqrt{1.85} = 284.87 \text{ rad/m}.$$


Module 2.3 Lossless Microstrip Line
Select: Impedance vs. Strip Width
σc = ∞
w
h
εr = 2.5
σ = 0
f = 10.0 [GHz]
Microstrip Characteristic Impedance
444.0
Z0
[Ω]
107.0
0.0
w [mm]
5.0
Input
Strip width w = 1 [mm]
Range
Substrate thickness h = 10 [mm]
Range
Frequency f = 1E10 [Hz]
Range
εr
2.5
Update
Output
Structure Data
w = 1 [mm]
h = 10 [mm]
w/h = 0.1
Z0 = 192.916 [Ω]
εeff = 1.843
up = 2.21 [10^8 m/s]
λ = 0.022 [m]
C´ = 23.457 [pF/m]
L´ = 872.987 [nH/m]
R´ = 0 [Ω /m]
G´ = 0 [S/m]
α = 0 [Np/m]
β = 284.327 [rad/m]