At 2 GHz in a 60 Ω system, a nominal 17 dB (16.99 dB) coupler is desired. Use microstrip on Rogers TMM10i board (1 oz. copper, 5.08 mm thick). a) Find the unitless coupling coefficient C and percentage of power coupled. b) Find the required even-mode Z_{0e} and odd-mode Z_{0o} characteristic impedances. c) Using Figure 7.30, find the land/trace widths W and separation S. d) Use Chapter 3 design equations for Z_0 = 60 Ω to find W_{60}, ε_{re}, v_p, and $L = \lambda/4$. e) Draw a fully-labeled top view sketch of the design. f) **EE 581 only:** Check answers for C, Z_{0e}, and Z_{0o} using design values in Rogers MWI. Use Snipping Tool to include relevant screenshots from MWI.

a) Per (7.20a), $C = 10^{-CdB/20} = 10^{-16.99/20}$ $\Rightarrow$ **$C = 0.141416$**

Per notes, % power = C^2 (100%) = 0.141416^2 (100%) $\Rightarrow$ **% power = 2.000 %**

b) Per (7.87a), $Z_{0e} = Z_0\sqrt{\frac{1+C}{1-C}} = 60\sqrt{\frac{1+0.141416}{1-0.141416}}$ $\Rightarrow$ **$Z_{0e} = 69.18\ \Omega$**

Per (7.87a), $Z_{0o} = Z_0\sqrt{\frac{1-C}{1+C}} = 60\sqrt{\frac{1-0.141416}{1+0.141416}}$ $\Rightarrow$ **$Z_{0o} = 52.04\ \Omega$**

c)

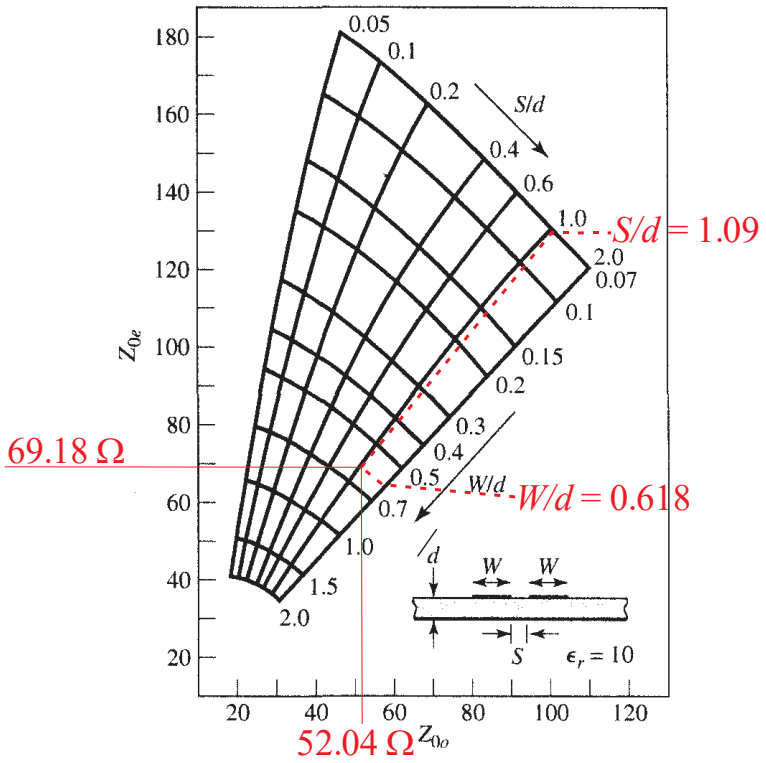


FIGURE 7.30 Even- and odd-mode characteristic impedance design data for symmetric coupled microstrip lines on a substrate with $\epsilon_r = 10$.

$S = S/d\ (d) = 1.09\ (5.08)$ $\Rightarrow$ **$S = 5.54$ mm**

$W = W/d\ (d) = 0.618\ (5.08)$ $\Rightarrow$ **$W = 3.14$ mm**

d) From datasheet, use $\varepsilon_r = 9.9$ for design purposes.

Per (3.197), $\frac{W}{d} = \frac{8e^A}{e^{2A}-2}$ for $W/d < 2$ where $A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right)$.

Check this case first. Here, $A = \frac{60}{60}\sqrt{\frac{9.9+1}{2}} + \frac{9.9-1}{9.9+1}\left(0.23 + \frac{0.11}{9.9}\right) = 2.53139$ and

$\frac{W}{d} = \frac{8e^{2.5314}}{e^{2(2.5314)}-2} = 0.64454 < 2$ (yes!).

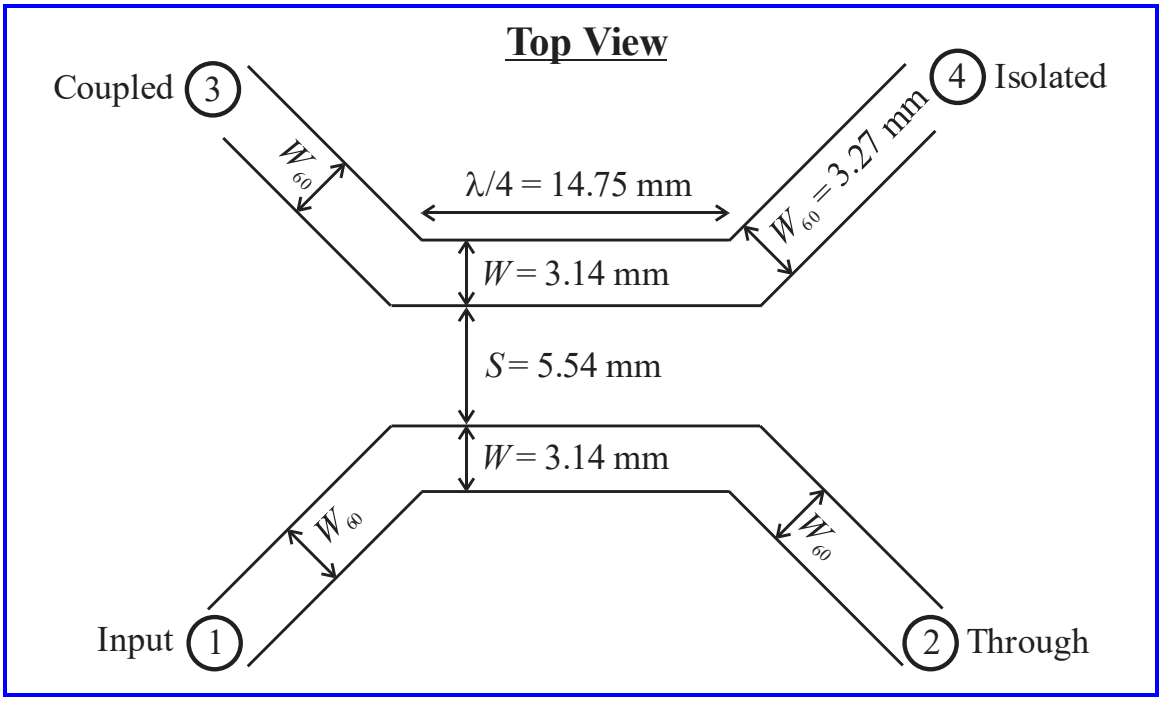
The land width is $W_{60} = 0.6445\,(5.08)$ $\Rightarrow$ **$W_{60} = 3.274$ mm**.

(3.195) $\varepsilon_{r,e} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\frac{1}{\sqrt{1+12\,d/W}} = \frac{9.9+1}{2} + \frac{9.9-1}{2}\frac{1}{\sqrt{1+12/0.6445}}$ $\Rightarrow$ **$\varepsilon_{r,e} = 6.455$**.

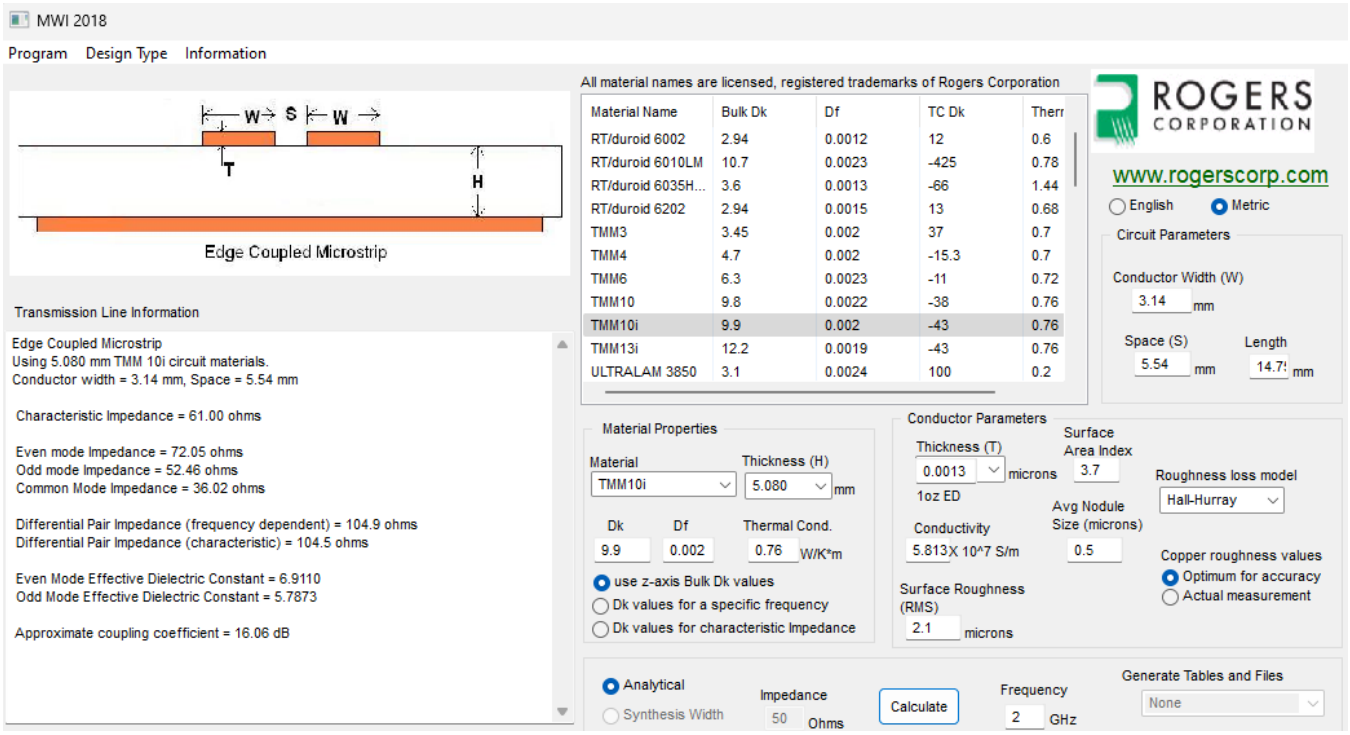
(3.193) $v_p = c/\sqrt{\varepsilon_r} = 2.9979\times10^8/\sqrt{6.4547}$ $\Rightarrow$ **$v_p = 1.18\times10^8$ m/s**.

$L = \lambda/4 = v_p/f/4 = 1.18\times10^8/2\times10^9/4$ $\Rightarrow$ **$L = 0.01475$ m $= 14.75$ mm**.

e)



f) Using default ε_r value in MWI-



Using design values ($W = 3.14$ mm, $S = 5.54$mm, & $L = 14.75$ mm) in MWI:

Parameter	Design	MWI	% diff.
C	16.99 dB	16.06 dB	5.5
Z_{0e}	69.18 Ω	72.05 Ω	4.1
Z_{0o}	52.04 Ω	52.46 Ω	0.8