

At 2 GHz in a $60\ \Omega$ 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 $Z_0 = 60\ \Omega$ 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), $C = 10^{-\text{CdB}/20} = 10^{-16.99/20}$

$\Rightarrow \underline{C = 0.141416}$

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

$\Rightarrow \underline{\% \text{ power} = 2.000\ \%}$

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

$\Rightarrow \underline{Z_{0e} = 69.18\ \Omega}$

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

$\Rightarrow \underline{Z_{0o} = 52.04\ \Omega}$

c)

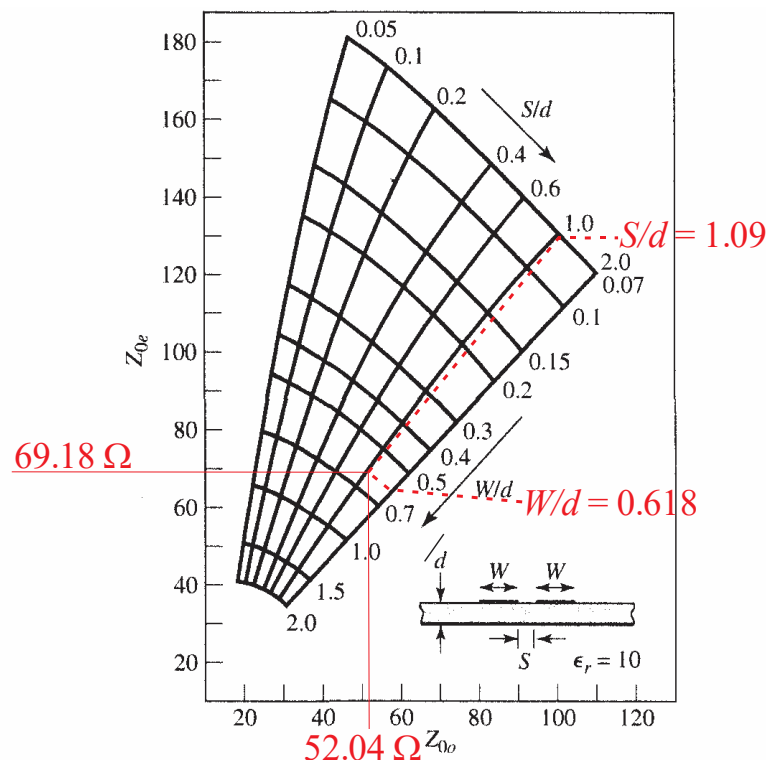


FIGURE 7.30 Even- and odd-mode characteristic impedance design data for symmetric coupled microstrip lines on a substrate with $\epsilon_r = 10$.

$S = S/d (d) = 1.09 (5.08)$

$\Rightarrow \underline{S = 5.54\ \text{mm}}$

$W = W/d (d) = 0.618 (5.08)$

$\Rightarrow \underline{W = 3.14\ \text{mm}}$

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

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

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

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

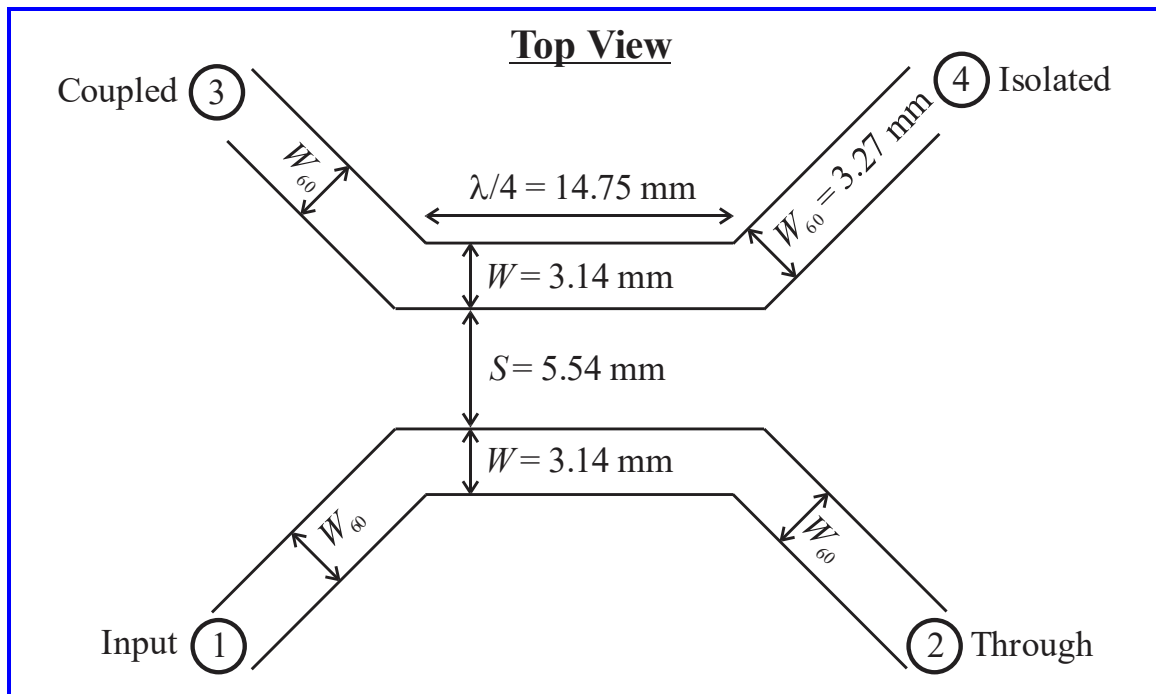
The land width is $W_{60} = 0.6445(5.08) \Rightarrow \underline{W_{60} = 3.274 \text{ mm.}}$

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

$$(3.193) v_p = c / \sqrt{\epsilon_r} = 2.9979 \times 10^8 / \sqrt{6.4547} \Rightarrow \underline{v_p = 1.18 \times 10^8 \text{ m/s.}}$$

$$L = \lambda/4 = v_p / f / 4 = 1.18 \times 10^8 / 2 \times 10^9 / 4 \Rightarrow \underline{L = 0.01475 \text{ m} = 14.75 \text{ mm.}}$$

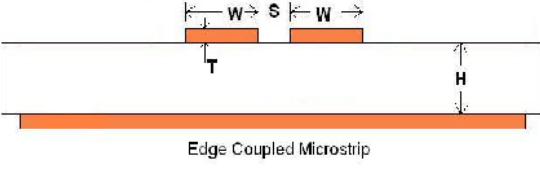
e)



f) Using default ϵ_r value in MWI-

MWI 2018

Program Design Type Information



Edge Coupled Microstrip

Transmission Line Information

Edge Coupled Microstrip
Using 5.080 mm TMM 10i circuit materials.
Conductor width = 3.14 mm, Space = 5.54 mm

Characteristic Impedance = 61.00 ohms

Even mode Impedance = 72.05 ohms
Odd mode Impedance = 52.46 ohms
Common Mode Impedance = 36.02 ohms

Differential Pair Impedance (frequency dependent) = 104.9 ohms
Differential Pair Impedance (characteristic) = 104.5 ohms

Even Mode Effective Dielectric Constant = 6.9110
Odd Mode Effective Dielectric Constant = 5.7873

Approximate coupling coefficient = 16.06 dB

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Material Name	Bulk Dk	Df	TC Dk	Therr
RT/duroid 6002	2.94	0.0012	12	0.6
RT/duroid 6010LM	10.7	0.0023	-425	0.78
RT/duroid 6035H...	3.6	0.0013	-66	1.44
RT/duroid 6202	2.94	0.0015	13	0.68
TMM3	3.45	0.002	37	0.7
TMM4	4.7	0.002	-15.3	0.7
TMM6	6.3	0.0023	-11	0.72
TMM10	9.8	0.0022	-38	0.76
TMM10i	9.9	0.002	-43	0.76
TMM13i	12.2	0.0019	-43	0.76
ULTRALAM 3850	3.1	0.0024	100	0.2

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English Metric

Circuit Parameters

Conductor Width (W)
3.14 mm

Space (S)
5.54 mm

Length
14.75 mm

Material Properties

Material: TMM10i Thickness (H): 5.080 mm

Dk: 9.9 Df: 0.002 Thermal Cond.: 0.76 W/K*m

☒ use z-axis Bulk Dk values
☐ Dk values for a specific frequency
☐ Dk values for characteristic Impedance

Conductor Parameters

Thickness (T): 0.0013 microns Surface Area Index: 3.7

1oz ED Conductivity: 5.813X 10⁷ S/m Avg Nodule Size (microns): 0.5

Surface Roughness (RMS): 2.1 microns

Roughness loss model: Hall-Huray

Copper roughness values:
☒ Optimum for accuracy
☐ Actual measurement

Analytical ☒ Synthesis Width

Impedance: 50 Ohms

Frequency: 2 GHz

Calculate

Generate Tables and Files: None

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