

EXAMPLE 2:

Band-stop Filter Design Using Stubs and coupled lines

Design a low-pass filter for fabrication using microstrip lines.
The specifications are:

- cutoff frequency;
fc1 = 2.9 GHz
fc2 = 3.1 GHz
- Stop frequency: fs = 2.95 GHz
- IL = 15 dB @ fs
- Impedance of 50 Ω
- 0.2 dB equal-ripple characteristic.
- Er = 9.8
- Thickness of dielectric = 25 mill

Solution

Start up the rf & microwave toolbox and select the band-stop filter tool.

Then select, from the menu, filter type Chebyshev and normalized LC-values as output.
Fill in the filter specifications and tab the Calculate button.

The image shows a software dialog box titled "Band Stop Filter Calculator". At the top, there is a circuit diagram of a Chebyshev band-stop filter. The diagram shows a series of components between two ports, Z1 and Z2. From left to right, the components are: a capacitor C1, an inductor L1, a capacitor C2, an inductor L2, a capacitor C3, an inductor L3, a capacitor Cn-1, an inductor Ln-1, a capacitor Cn, and an inductor Ln. Below the diagram, the filter type is set to "Chebyshev". The input parameters are: fc1 = 2.9 GHz, fc2 = 3.1 GHz, ripple = 0.2 dB, fs = 2.95 GHz, IL @ fs = 15 dB (highlighted with a yellow arrow), Z0 = 50 Ω , and N = 3. There are "Calculate" and "Plot" buttons. At the bottom, the calculated component values are listed: Z1 = 1, Z2 = 1, C1 = 0.081884 F, L1 = 12.212391 H, C2 = 13.007485 F, L2 = 0.076879 H, C3 = 0.081884 F, L3 = 12.212391 H.

Parameter	Value	Unit
fc1	2.9	GHz
fc2	3.1	GHz
ripple	.2	dB
fs	2.95	GHz
IL @ fs	15	dB
Z0	50	Ω
N	3	
Z1	1	
Z2	1	
C1	0.081884	F
L1	12.212391	H
C2	13.007485	F
L2	0.076879	H
C3	0.081884	F
L3	12.212391	H

Figure 1: Band-stop filter calculator dialog

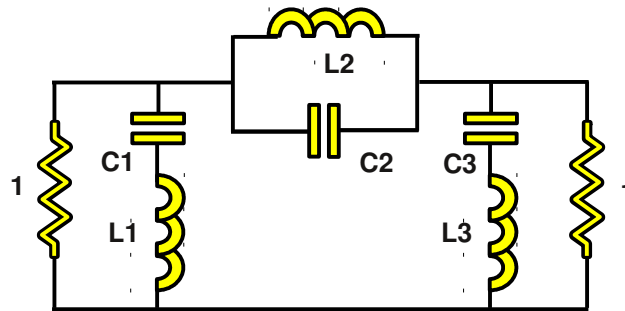


Figure 2: Band-stop prototype filter

The normalized band-stop prototype element values are:

- L1 = 12.2124
- C1 = 0.0819
- L2 = 0.0769
- C2 = 13.0075
- L3 = 12.2124
- C3 = 0.0819

Z0	1	Ω	Z0'	0.9607	Ω
L	12.21239	H	C	0.081884	F
Lp	25.4248	H	Ls	23.4641	H
C1	0.0409	F	M	24.4248	

Figure 3: Kuroda's Identities dialog

We will use Kuroda's identity nr 8 to convert the shunt LC elements into Brune sections.

Select tool Filter Design and the tab button Kuroda's Identities.

Fill in the values for Z0 (Zin, Zout) and L (L1,L3)

After using Kuroda's identities we getting the circuit of Figure 4.

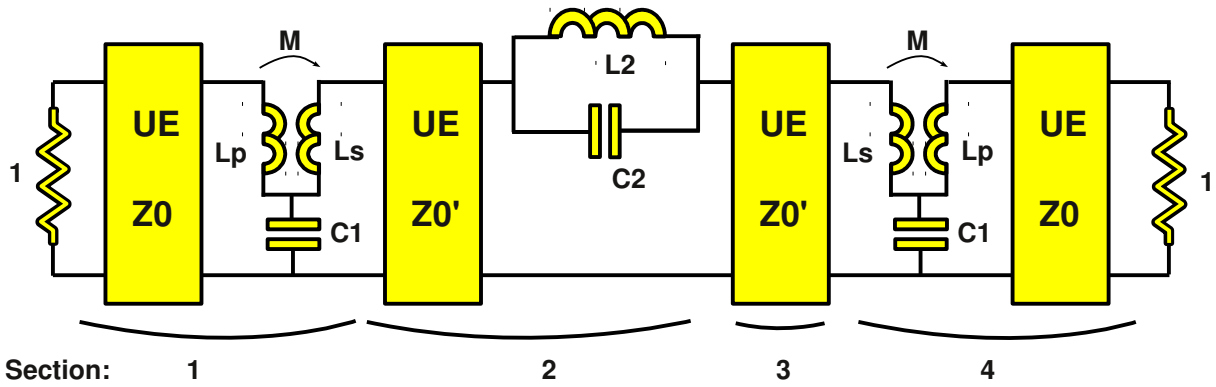


Figure 4: Band-stop filter after using Kuroda's Identities

$Z_0 = 1$
 $Z_0' = 0.9607$
 $C_1 = 0.0409$
 $C_2 = 13.0075$
 $L_2 = 0.0769$
 $L_p = 25.4224$
 $L_s = 23.4617$
 $M = 24.4224$

Now we will use coupled line equivalent circuit nr 12 and 14 to convert the lumped elements into coupled line sections with shunt stubs.

According to Richard's transformation all lengths for coupled line and stubs are $\lambda/8$.

(The frequency at which the lines are $\lambda/8$ is equal to $\sqrt{(2.9 \cdot 3.1)} = 2.9983$ GHz)

Coupled Line Equivalent Circuit

Z_0	1	Ω	C	0.0409	F
L_p	25.4224	H	M	24.4224	
Z_{oe}	1.3253	Ω	Z_{oo}	0.7534	Ω
Z_1	1.0393	Ω	Z_2	0.0006	Ω

12

Figure 5: Series and shunt equivalent circuit nr 12 dialog

Coupled Line Equivalent Circuit

Z_0	0.9607	Ω	C	13.0075	F
L	0.0769	H	Z	1.0376	Ω
Z_{oe}	1.3201	Ω	Z_{oo}	0.7551	Ω

14

Figure 6: Series and shunt equivalent circuit nr 14 dialog

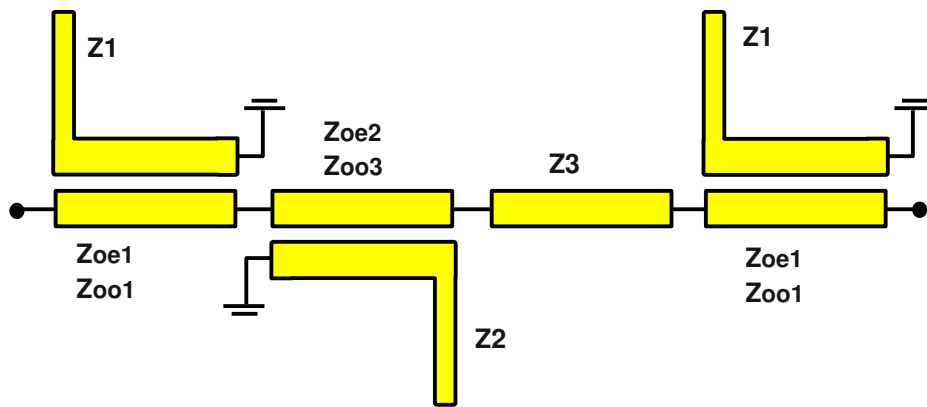


Figure 7: Band-stop filter using transmission lines. All lengths are $\lambda/8$ @ f_o

	<i>Normalized values ($Z_0 = 1$)</i>	<i>De-Normalized values ($Z_0 = 50\Omega$)</i>
Z1	1.0393	51.97
Z2	0.9604	48.02
Z3	1.0376	51.88
Zoe1	1.3252	66.26
Zoo1	0.7534	37.67
Zoe2	1.3201	66.01
Zoo2	0.7551	37.76

Next step is to convert the ideal transmission lines to microstrip lines.
 Select tool Microstrip Calculator and fill in the values for ϵ_r (9.8) and substrate height (25 mil).
 Fill in a phase of 45 deg ($\lambda/8$) and F is the center frequency (2.9983 Ghz)
 Leave all other parameters to default.

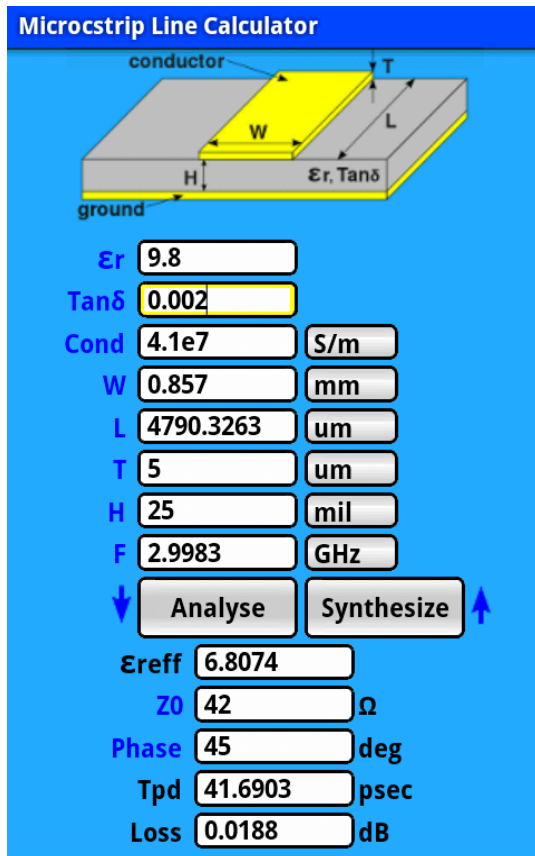


Figure 9: Microstrip line calculator dialog

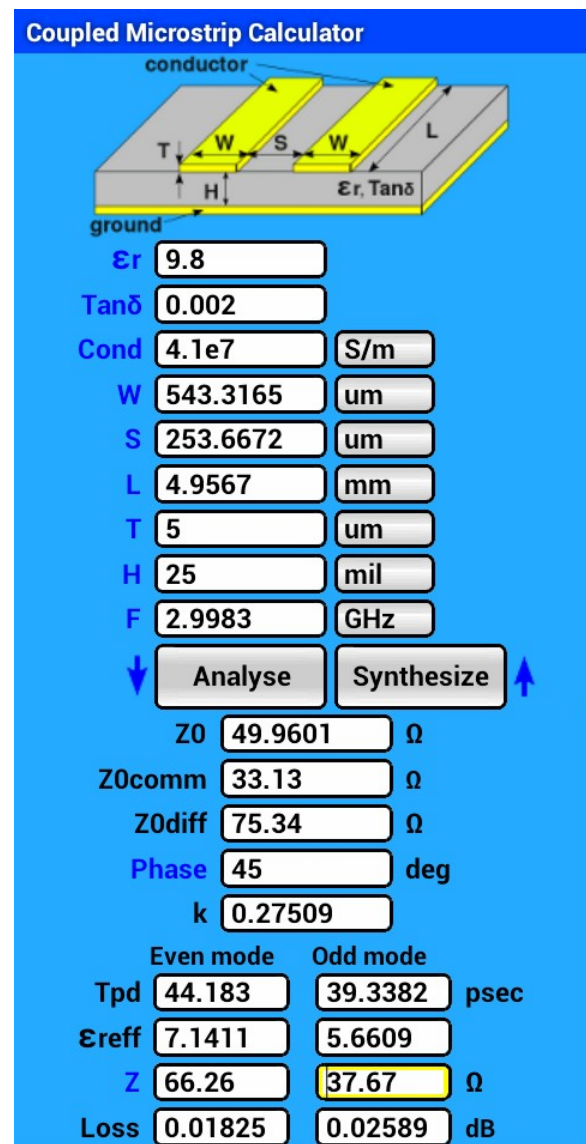


Figure 8: Coupled microstrip calculator dialog

Fill in the desired impedance of the transmission lines and synthesize the width and length of the microstrip lines.

Next step is to convert the coupled line sections to microstrip lines.

Select tool Coupled Microstrip Calculator (Figure 8) and fill in the values for ϵ_r (9.8) and substrate height (25 mil).

Fill in a phase of 45 deg ($\lambda/8$) and F is $f_0 = \sqrt{f_{c1} \cdot f_{c2}} = 2.9983$ GHz

Leave all other parameters to default.

Then set the synthesize mode to **Z odd & even**.

Fill in the desired Z even and Z odd impedance and synthesize the width (W), length (L) and the gap (S).

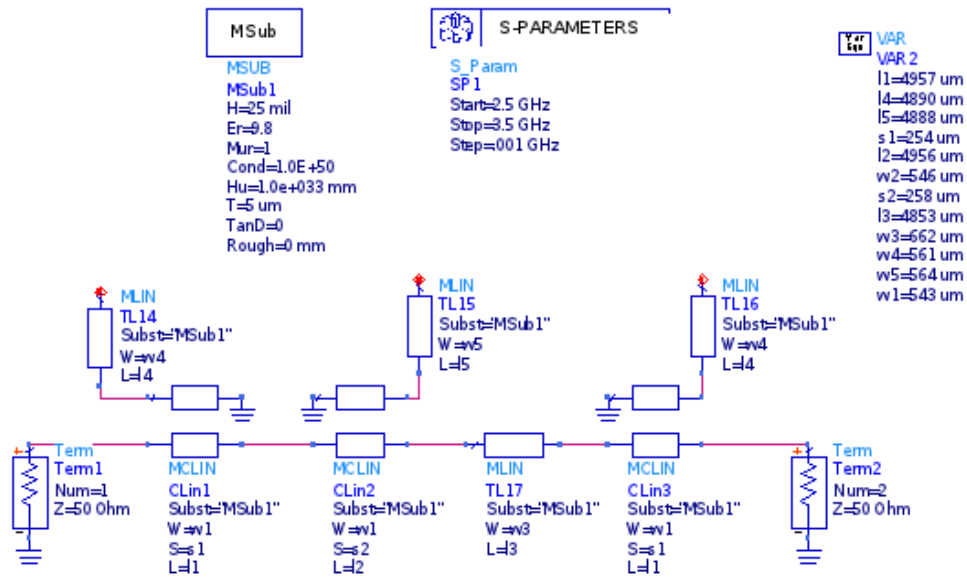


Figure 10: ADS circuit of the microstrip band-stop filter

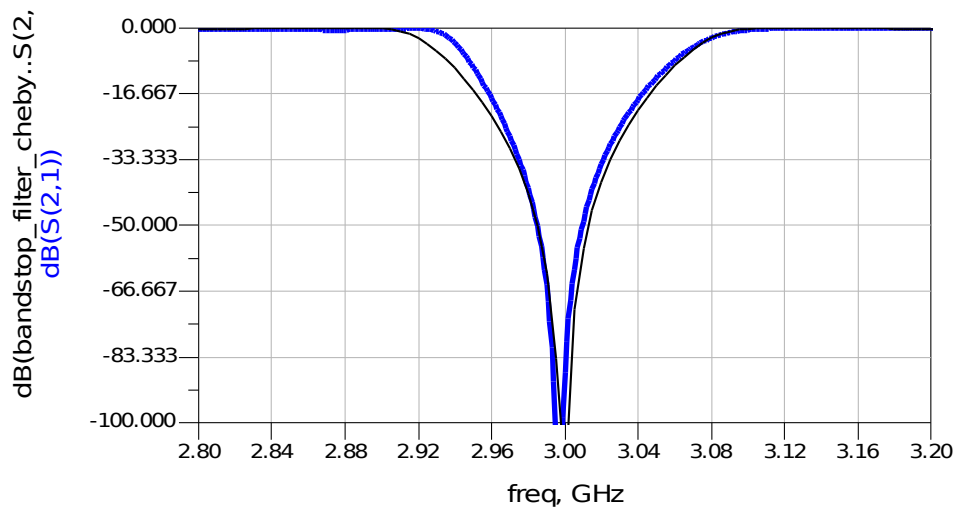


Figure 11: ADS simulation of the band-stop filter. **Blue:** Using microstrip lines. **Black:** Lumped circuit.